VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

No. LIX.—NOVEMBER, 1873.—Vol. IX.

VENTILATION OF BUILDINGS.*

By W. F. BUTLER.

I do not claim to have discovered anything new in the art of ventilation. All I have endeavored to do in the following pages is to lay down principles, which shall be applicable to almost every case where ventilation is required.

One object of the paper is to insist upon the great and increasing importance of the subject, and, if successful in this, I am satisfied that it will not have been read in vain.

Before proceeding further, I think it will be desirable to explain what I mean by the term "Ventilation." Briefly, it is this,—a gradual, continuous and complete changing of the air contained in any structure, a substitution, in fact, of fresh air for foul, but so gradual a substitution that the motion of the air should be imperceptible.

Of course, in factories, imperceptibility need not be so much regarded, and in the cases of sewers and underground railways, it is obvious that any method may be followed which promises the most perfect results.

The importance of the subject under consideration, which can hardly be overestimated, has been the constant theme of writers on ventilation; thus, Dr. James Johnson, in a work called "A Diary of a Philosopher," says that all the deaths resulting from fevers are but as a drop in the ocean, when compared with the numbers who perish from bad air.

It is to the efforts of science that we must look for an alteration in so disastrous a state of things, and men of science may be assured that Society will ere long demand, not, as an eminent Philosopher is reported to have said, a new faith—we neither look for nor expect that—but a longer life, increased freedom from disease, and greater means of enjoying sound health while life lasts.

I believe, we cannot doubt that much of the apathy manifested towards our subject by people generally, results from the abortive experiments and useless methods so often tried, and resorted to for the purpose of supplying the want of ventilation.

Before I leave this part of my subject, I will mention one other difficulty in the way of ventilation, and this by no means a small one—I mean the cost.

Although efficient ventilation will not cost a very large sum per room, it cannot be denied that somewhat will be added to the expense of the house, and this "somewhat" the speculative builder never will add until he finds intending tenants and purchasers refuse to take houses which are not properly ventilated.

As with houses, so with all other buildings and works; if we make up our minds to ventilate them, we must also resolve to pay for it.

I fear that even persons who build houses for their own occupation, are but little in advance of the speculative builder, as far as any recognition of the absolute

*From a paper read before the Society of Civil and Mechanical Engineers.

necessity of efficient ventilation is concerned. Many hold to such crude devices as open windows and doors. Others think a hole of any size or in any part of the wall quite sufficient, while, I believe, the majority pooh-pooh the whole question.

It then becomes the duty of scientific men, and bodies, to educate the public up to the recognition of the fact, that ventilation is every whit as important as drainage, to individual houses, and that man can no more live in a foul atmosphere than he can while constantly imbibing poisonous water.

Ventilation is a want arising chiefly from modern ways and customs, and is therefore a comparatively new branch of science, and we owe our present knowledge of the subject especially to modern researches and discoveries.

That ventilation is a new requirement will, I think, be readily acknowledged, when we consider the every-day life of our forefathers who lived prior to the close of say the 17th century. We shall see that, in by far the larger number of cases, theirs was an out-of-door life. Their days spent mostly in the field, either in the sports of the chase, in war, or in the occupation of husbandry.

If they were wealthy, their halls were large and lofty with enormous fireplaces, and loosely fitting doors and windows, from which innumerable currents of air rushed to the fires. If they were poor, they had, amid all the dirt and wretchedness which surrounded them, no want of air, as any one who has seen an old English or Welsh Cottage will readily admit.

The windows, too, down to nearly the period I have named, were, in most cases, filled with nothing better than shutters or louvre boards, glazing being then a rarity, at least in houses of the commoner sort, for though glass was known to the Phœnicians and to the later Egyptians, whose glass works at Sidon and Alexandria were famous throughout the then civilized world, and although it was employed by the Romans to some extent in their windows, as is shown by the remains found in Herculaneum, window glass was not manufactured in England, I believe, prior to the middle of the 16th century and must up to that time at least, and probably long after, have been an article of luxury, while its substitutes, oiled paper or plates of horn, can hardly have been in general use, at least in the dwellings of the poorer classes in country districts.

In cities and towns, doubtless, greater comfort, if not better sanitary arrangements, prevailed. But these were always the strongholds of fever, plague, and cholera. In towns the "black death," so much dreaded in the 14th century, had its headquarters, and from them it extended its devastating arms into all the surrounding country. I believe that to defective ventilation not less than to bad drainage and insufficient water supply, may be traced these scourges of the human race which now seem rapidly giving up their strongholds to the invading forces of science.

We cannot wonder on looking at such places as the hall of Bodiam Castle, for instance, in which were two fireplaces, each about 25 ft. wide and 7 ft. high, that people found a settle, a comfortable article of domestic furniture, and viewed the chimney corner, where they crowded like smoked hams, as the choicest parts of the room. Nor must we be surprised when we are told that the curtains enclosing the couches whereon reposed the proudest beauties of the land shook in response to every wind that blew.

If the wretched hole which they show in Carnarvon Castle as the birthplace of Edward II. be indeed the room in which that unhappy prince first saw the light, I can only say that whatever advantages the men of a former age may have had over us, certainly domestic comfort could not be said to be one of them.

The first person who seems to have turned his serious attention with any practical result towards the subject of this paper, at least in England, was, I believe, Dr. Desaguliers, who, in 1723, was called in to ventilate the House of Commons, upon which Wren had before tried his hand.

The Doctor discharged his commission with success, but he unfortunately provoked the hostility of one very important individual, viz., the housekeeper, a certain Mrs. Smith, who effectually extinguished him by not lighting the fires upon the action of which his system depended, until the House had sat for some time, and the chamber had got thoroughly heated, so that we cannot wonder some of the members should have considered the design of cooling the House was frustrated, and requested the Doctor to employ other means. He accordingly invented a centrifugal wheel,

or blowing machine, so constructed as to force air either into or out of the House, according as either was required. This machine was put in charge of a man called the ventilator, whose duty it was to wait upon Mr. Speaker every day for orders. Dr. Desaguliers was next applied to by the the Admiralty to ventilate ships, but here, as might be expected, he got inventors' allowance, viz., more kicks than halfpence. All his troubles with Mrs. Smith were nothing compared with the treatment he and his invention received from Sir Jacob Ackworth, the Surveyor to the Navy, who seems to have been the beau ideal of an official. When the Doctor attended by appointment on board the ship in which his machine was to be tried, Sir Jacob did not appear, but hearing that the company were pleased afterwards told Dr. Desaguliers that at the next experiment he (the Doctor) need not attend, as the carpenter could manage the ventilation.

When the second trial came off, Sir Jacob had scuttle holes cut at each end of the ship and then hoisted enormous wind-sails, and when, as might naturally be expected, he found that more air came through his windsails, which were about 2′.6″ diameter than through the Doctor's tubes, which were 5″×3′; he said he could not stay longer, and that he was sorry the machine had answered no better. Sir Jacob, however, sent his "humble duty" to Dr. Desaguliers, and thought his invention might be a very pretty thing in a house.

The Lords of the Admiralty never came near nor gave themselves any trouble about it, and so the Doctor found his invention would not be used in the Navy.

The next person who came forward in the cause of ventilation for the Navy, was Mr. Sutton, a brewer by trade. He made use of the fire which cooked the provisions of the ship's company as the motive power, laying pipes from all parts of the ship to the ashpit under the grate. When the ashpit-door was closed no air could get to the fire except throught the pipes.

The result was considered satisfactory, and the apparatus was ordered to be fitted up on board the Norwich man-of-war.

Mr. Sutton had also to contend with Sir Jacob Ackworth, but he had found powerful friends in Dr. Mead, the King's Physician, and Sir Charles Wager, so that the old knight's opposition was rather passive than active.

This, I believe, is one of the first, if not the first, instance of the scientific use of the common fire as the power for ventilating any structure. This method has been called thermo-ventilation by Mr. Bernan, to whose work, as well as to those of the inventors whose names I have mentioned, I am indebted for many of the particulars given above.

However successful Mr. Sutton may have been in getting his apparatus fixed, he failed when he applied to the Admiralty for some reward for his sevices; they simply took no notice of him or his petition, although the Norwich had returned to England from the Guinea Coast, with the loss of only two men, and the Captain reported her singularly healthy.

Meanwhille, a certain Dr. Hales had been pressing an invention of his own upon the notice of my Lords. This he called a ship's lungs. The machine was, in fact, a magnified bellows, differing somewhat in construction from common bellows certainly, but the same as far as action was concerned. It consisted of a large square case with valves, enclosing a hinged midriff, which rose and fell by the action of a long handle or lever, worked by some of the ship's company. The whole machine was cumbersome, requiring about four men per hour to work it, and could not, certainly, compare with the blowing-wheel of Dr. Desaguliers. It soon fell into disuse, and became a thing of the past.

Mr. Sutton, who had at last got £100 from the Admiralty, exulted over the failure of the ship lungs, but his triumph was short-lived, for, in the course of a few years, he found that he was left out in the cold also, and the old wind-sails were again on duty.

The illustrious names of Count Rumford and Sir H. Davy, as well as those of a host of other persons less celebrated, which figure in the annals of ventilation, attest the importance of the question. It is time, however, for me to take leave of this portion of my subject, on which volumes might be written, and to consider the causes which make ventilation a necessity.

These may be classed under different heads, viz.: 1st, In private houses. The necessity for ventilation will arise from commonly (A) the presence of fires; (B) artificial light; (C) the presence of persons living in the house, that is from the air required by them, as well as the exhalations

from their bodies, and (D) from badly constructed water-closets, cesspools and drains. 2d. In factories there will be, in addition to the above causes, the presence in the air of a vast quantity of minutely-divided fibre and dust, which is highly prejudicial to the health of the workers, and also the fumes from chemicals, etc., where the manufacture of such is carried on. 3d. In sewers. The necessity of sufficient ventilation will almost entirely arise from the generation of poisonous gases by the putrid filth carried down. 4th. And in underground railways, the fires of the engines, and the saturation of air by the waste steam, will render ventilation, in certain cases, necessary.

Considering these cases in the above order, we have 1st, in dwelling houses (A), the presence of fires.

At first sight it would seem an error to include this under the head of causes which make ventilation necessary. As fires are often, indeed mostly, the only means of ventilation in private houses. But under the term I include not only the removal of foul air, but the supply of fresh, and from this point of view it will be seen that the common fire is a very great consumer of fresh air, and requires a supply of that quite as much as of the fuel which feeds it.

It may be as well to mention here some of the well-known facts connected with the combustion of fuel.

The fuels commonly used are composed, principally, of carbon and hydrogen in about the following proportions:—

Name.	Carbon	Hydrogen.	Ashes, &c.	Water.
Coal.....	.812	.048	.140	....
Coke.....	.850	...	.150	....
Wood.....	.408	.042	.350	.200
Charcoal...	.930	....	.070	....
Peat.....	.464	.048	.288	.200

Now, combustion consists in the union of oxygen gas with the elements carbon and hydrogen, and the result is a development of light and heat, and the formation of carbonic acid and water, the carbon of the fuel uniting with the oxygen of the air to form carbonic acid, and the hydrogen doing the same to form water.

Carbon exists in its pure and crystallized form as the diamond, and this beautiful gem is combustible in oxygen gas, burning entirely to carbonic acid. This experiment has been tried, however, only in the laboratory.

One pound of carbon requires for its combustion 158 cubic ft. of air, while the same weight of hydrogen requires 473 cubic feet. From these facts it will be seen that the different fuels mentioned above will take for their proper combustion the following minimum quantities of air, viz.:—

Coal.....	148 cubic feet	per pound.
Coke.....	134 "	
Wood.....	65 "	
Charcoal.....	147 "	
Peat.....	81 "	

There is a certain quantity of oxygen in coal, wood, and peat, which somewhat reduces the amount of atmospheric air required by these fuels.

From the above tables—for which I am indebted to the researches of Péclet, Playfair, Regnault, and others, and which assume the temperature of the air to be 26 deg. F.—it will be seen that the ordinary fire plays no unimportant part in the consumption of air; for, if we assume one pound of coal per hour as the quantity required, then 148 cubic ft. of air will be consumed in that period, or 2.46 ft. per minute, or 2,072 cubic ft. per day of 14 hours.

These, as I have said, are minimum quantities. In practice, at least double must be allowed, as a large percentage will escape unconsumed.

In the case of the common fire, the products of combustion do not certainly escape into the room, but the air to supply the fire is required all the same, and I feel sure that not in one house in a hundred is this supply ever thought of, but is left to chance, and the cracks in the doors and windows from which drafts whistle across the room in every direction.

The second cause (B)—artificial light—requires far more serious consideration than the fire, for, commonly, the products of combustion are passed directly into the room, and are breathed in a diluted form by the persons in it.

The introduction of coal gas has been most pernicious in this respect, for few houses are built with any regard to the method of lighting, nor are the ways in which the gas is generally burnt calculated for anything but to do the greatest amount of injury to the persons using it. Some forms of gas-light, such as the sun burners and the ventilating globe light, are compara-

tively free from defect in these respects, but I have never seen the latter used save in one or two private houses, and the former are almost entirely confined to offices and public buildings.

I have experienced some difficulty in obtaining the quantity of air consumed by the ordinary bat's-wing or fish-tail burner when lighted. But taking the Argand burner using 5 ft. of gas per hour, and 45 ft. of common air in the same time, as a standard, and knowing that the common burners burn from 2 to 6 ft. per hour, according to size and pressure, I think I shall be safe in calculating the average consumption of gas by the common burners at 4 cubic ft. per hour, and the amount of air at 36 cubic ft. per hour.

Now a room 25 ft. long by 16 ft. broad, and 10 ft. 6 in. high, will contain 4,200 cubic ft. of air, but a deduction must be made for furniture, etc., of at least 10 per cent., leaving 3,780 cubic ft., or say 3,800, as the net quantity of air in the room.

Such a room will require at least three gas burners to light it, and these, as we have seen, will consume 108 cubic ft. of air per hour, rendering it absolutely unfit for breathing by depriving it of its necessary proportion of oxygen.

Ordinary candles do not vitiate more than 11 cubic ft. of air per hour, per candle.

As the chief constituents of coal gas are carbon and hydrogen, so the principal results of its combustion are carbonic acid and water. This water, in the form of vapor saturates the air of the room, which has a greater capacity for moisture when warm than when cold. This may be readily seen if, in a close warm room, we examine the windows, where the moisture will be found condensed, and perhaps running down the glass in streams.

The same effect will be produced by placing a glass bottle filled with cold water on the table, the moisture will settle thickly upon it like dew upon the grass on a clear night.

The reason is this. The air cooled by contact with the cold glass is no longer able to sustain the moisture, and the latter is therefore precipitated in the form of dew.

(C.) The third cause I have mentioned is the presence of living beings in the room. Let us now consider the effect of this.

Man's body is a furnace, a slow combustion furnace if you will, but still a furnace, and the waste from this human furnace is precisely the same as that from any other furnace, viz., carbonic acid and water. To quote the words of Professor Tyndall: "In the animal body the carbon and hydrogen of the vegetable are again brought into contact with the oxygen from which they had been divorced, and which is now supplied by the lungs. Re-union takes place, and animal heat is the result. Save as regards intensity, there is no difference between the combustion that goes on within us, and that of an ordinary fire." We see then of what vital consequence is the presence of oxygen in the atmosphere. Without it fires and lights will not burn, our food will not digest, and the blood remains unpurified, as is shown by the pale faces and purple lips of people living in close warm rooms. These are the forerunners of certain death to persons deprived of the life-sustaining oxygen.

Atmospheric air consists of a mixture of several gases, for though it is commonly said to be formed of oxygen and nitrogen in proportion of 21 volumes of the former to 79 of the latter, in each 100, yet several other gases are mixed with these. The composition of air varies with its situation. Thus, inland air is not of precisely the same composition as that near the sea coast, where there is said to be a greater proportion of ozone. On rocky mountains there is more carbonic acid than is found in the valleys.

The quantity of air required by a man varies with the state of his body. Thus a man at hard work or violent exercise may require even five times as much air as the same man when asleep.

This amount of air has been variously estimated, but I think we may safely take the following calculation by Box to be correct. He states that an ordinary man takes 20 respirations per minute, of the capacity of 40 cubic in. each, thus vitiating 28 cubic ft. per hour. Added to this, there is the quantity of air saturated by the moisture evolved to be considered. According to Dumas this quantity in the form of vapor equals .0836 of a pound of water per hour, which is sufficient to half saturate, for air should not be more than half saturated to be pleasant—187 cubic ft. of air at 62 deg. Fahr.

We thus see that to be in good health a man must have 215 cubic ft. of air per hour for his own use. Sick persons require very much more than this.

(D.) There is one more source of contamination of the air of our houses, which often forces itself unpleasantly upon our notice. I mean the foul gases which escape from drains and water-closets. It is not too much to say that if architect and builder always did their duty, no foul air from any drain or closet ought ever to enter a house, and that the negligence of one and the ignorance, or worse, of the other, must be charged with a greater destruction of human life and with causing more disease every year than has been produced by the bloodiest battle recorded in history,

It is impossible to estimate correctly the air contaminated from this source, but I hope to show how such contamination may be avoided.

As a summary of results we see, that in a room of the net cubic capacity of 3,800 ft., having a fire burning, inhabited, by say six persons, and lighted by three gas lights, there will be required every hour, so that the inmates may be healthy, 1,694, or say 1,700 cubic ft. of fresh air at 60 deg. F.

But air expands $\frac{1}{491}$, or 0.00204, of its volume for every degree F. it is heated; it is obvious from this that, assuming the temperature of the outer air to be 32 deg. F., we shall not require to admit so much cold air into the room by about 100 cubic ft., but exit must be provided for the full quantity.

Professor Tyndall gives the following table of expansion of gases for an increase of temperature equal to 1 deg. F. :—

Hydrogen	0.00203
Air	0.00204
Carbonic Oxide	0.00204
Carbonic Acid	0.00206
Protoxide of Nitrogen	0.00207
Sulphurous Acid	0.00217

We see from this that gases obey the almost universal law, and expand with increased heat. Upon this fact is built the whole system of thermo-ventilation, and upon its due appreciation depends success in this particular branch; for it follows that as gases expand so are their densities decreased, and they are lifted upwards by the heavier air without; rising, not because they are light, but because the outer air is colder and consequently heavier.

The following is a table of specific gravities of gases taken from the experiments and researches of Regnault and others. Atmospheric air being 1 :—

Air	1.00000
Hydrogen Gas	0 06926
Oxygen Gas	1 10563
" "	1.11100
Nitrogen Gas	0.97137
Carbonic Acid	1 52901
" Oxide	0.9727
Protoxide of Nitrogen	1.5252
Sulphurous Acid	2.2464
Sulphuretted Hydrogen	1.1710
Vapor of Water	0.6235

This table shows us how varied are the densities of different gases. Thus, while hydrogen is more than 14 times lighter than air, sulphurous acid is about $2\frac{1}{4}$ times heavier.

There is another property of gases which merits our consideration besides that of density, and this is the power they have of mixing with one another.

The gases which compose common air, for instance, are not chemically combined to form any new substance; they exist each one of them just as if the others were not present. When we consider this, and the fact that they are of different densities, it would fill us with astonishment that they do not settle, as it were, away from one another, the heavier oxygen falling to the ground, and the lighter nitrogen ascending to the clouds, did we not know of this law of combination, which is called the law of diffusion of gases. Professor Graham expresses this law by saying that *the diffusive power varies inversely as the square root of the density of the gas itself.*

A simple but beautiful experiment of the Professor's illustrates the law.

I have stated that in the room before mentioned we require at certain times—and all works should be calculated for the greatest possible duty they may have to perform—space for 1,600 cubic ft. of fresh air to enter, and far 1,700 ft. to leave the room every hour.

I am aware that any proposal to admit cold air into a room will meet with opposition, and were houses built upon principles worthy of our civilization it might easily be avoided. I think, however, that, with proper means, the possible evil may be so reduced as to be practically unfelt. I am also now treating of existing houses which could not well be rebuilt or altered.

I would propose that in such houses where the want of ventilation is felt, the openings for admission of fresh air should be made as near the floor of each room as possible. For it will be seen from what has gone before, that the cold air will, on

entering, be heavier than that in the room, which it will gradually force upwards and out through the foul air exit channels.

Many people will probably say, "Oh what a draft there would be to one's legs and feet." Doubtless if a good sized hole be cut through the wall, say directly opposite the fireplace, and you shut the door and stand between the opening and the fire, very likely you would feel rather cool about the inferior extremities. But I do not propose a thing of this kind.

The fire must have its own separate supply, which should be given by means of a pipe leading through the hearth-stone, as is sometimes done now, with the opening facing the fire, which latter, as it constantly acts the part of a pump, will take care to get its own allowance from the nearest source.

We have therefore only the forcing power of the difference in weight, between columns of air, of equal height, but of the different densities due to difference of temperature between the external air and that in the room. This difference I have assumed to be 30 deg.

This forcing power will cause the air to enter the room with a velocity equal to that which would be acquired by a body falling a distance equal to the difference in height between a column of air 10 ft. 6 in. high at 62 deg., in the case I have assumed, and the same air at 32 deg.

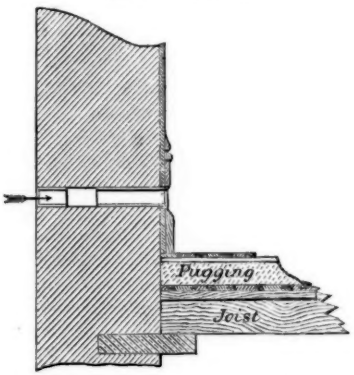
This difference will be equal to .643 of a foot, and the speed of the entering current will, by the rule for falling bodies, be 6.43 ft. per second.

Assuming that all the air enters through one opening, then about 8 sq. in. would be sufficient. It will be obvious, however, that it is not advisable to admit air at so high a velocity as this, nor would one inlet be so efficient as several.

I would propose, then, for existing rooms, that the inlets should be made in the side walls, near the floor, and in as many different sides of the rooom as its situation will allow. That these be made larger towards the room, and that they should be enclosed by metal gratings made ornamental on the outer and inner faces. The sketch marked A will show generally what I mean.

There is one point to which I would call your particular attention, and this is the fine wire gauze screen shown just behind the ornamental front. This serves a very useful purpose, for it screens and breaks up the entering current of air, preventing all drafts, and, if the openings have sufficient area, allowing the incoming air to mingle so gently with that now in the room, that its presence is not felt save in a pleasant way.

FIG. 1.—SECTION.

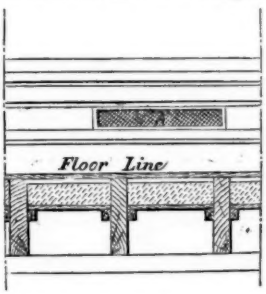


I attach great importance to this screen, and to the size of the openings.

We must now proceed to consider the best position for the exit.

I think a little consideration will show us that the heated chimney affords the best possible means under the circumstances. By causing the foul air to escape into the chimney we increase the ventilating power

FIG. 2.—ELEVATION.—A is the grating.



very considerably. We have no longer to deal with the small difference before mentioned, but may calculate upon the whole height of the chimney, above the opening, through which the foul air enters it, and have the difference between this column of air highly heated as it is, and that of

another of the density of the outer air, as the force at our disposal.

Care must be exercised in the choice of a valve to close this opening against down draft. The best which has come under my notice is formed of a series of leaves or flaps of mica enclosed in a metal case. The flaps are very light, and, being hung from the top, are absolutely secure against return currents. The front may be made as ornamental as can be desired.

The heated and spent air from the gas light should be conveyed away immediately when possible.

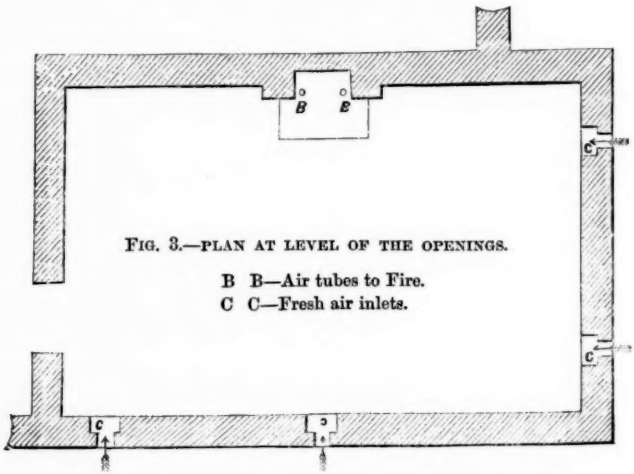


FIG. 3.—PLAN AT LEVEL OF THE OPENINGS.

B B—Air tubes to Fire.
C C—Fresh air inlets.

The ornamental flower which is commonly placed in the centre of the room may be pierced through. The opening thus formed being boxed in between the joists with thin sheet metal connected with a tube for conveying the waste gases into the chimney or outer air.

The register of the fire grate will form a regulator, by closing or opening which the draft through the escape valve may be increased or diminished.

Exercise of proper skill and judgment in the form and placing of the inlets, and in the construction of the exit, will insure comfortable ventilation in rooms built with no special provision for it.

The tube which supplies the fire should have a valve to close it, so that when necessary the whole pumping power of the fire may be applied to sucking in fresh air through the room.

I will now refer to the last source of contamination mentioned above, viz., foul drains and water-closets.

Any unpleasantness from the former will commonly arise from faulty design, or malconstruction. A drain is ill designed which passes under any portion of the house, unlesss no other way is possible. Also where no provision is made for ventilating, and where it is not of ample size.

A drain unevenly laid, built of inferior materials badly jointed, or not properly connected with the main sewer, is badly constructed.

Of course, in use, a drain may become stopped by accident or design; this is another matter; all works are liable to accidents, but a mishap of this nature will soon show itself by the bursting or overflow of the drain.

The remedies for bad smells from drains are, 1st, the proper laying of the drain. It should be formed of socketed pipes, in no case less than 4 in. diameter, 6 in. will often be better, or even 9 in. pipes for large houses. Sufficient fall should be given, not less, if possible, than 3 in. in 10 ft. The pipes should be laid in good concrete, and jointed with Portland cement. 2d. The drain must be trapped. The common siphon trap is the best form for general use, and I believe a single trap is preferable to double, for with two traps, when the water has passed the first it compresses the foul air, which escapes through the upper one into the house.

3d. All injurious escape may be prevented by ventilating the drain. A pipe should be connected with the siphon, on the summit of the bend between the water which closes the trap and the leg of the siphon which joins the drain. This pipe Dr. Carpenter says should be of nearly the same bore as the siphon, and should be carried up outside the house above the eaves, as far from any window as can be. Outside a chimney is a good place, but the opening should not be above or near the top of the chimney. Care must be taken to make the joints in the pipe gas-tight. The rain-water pipes should not be used as ventilators to the drains.

Unpleasantness from the water-closet will almost always arise from its position. This, as we all know, is commonly the very worst which could be found, viz., under or close to the stairs, the well of which forms a shaft for conveying foul air into all the bed-chambers.

I have seen in London a water-closet opening into the dining-room, but even this is hardly so objectionable as the usual position.

The water-closet should, where possible, be outside the house. I do not mean detached, but separated by such a space as will allow of double doors, with sufficient distance between them for ventilation.

The building itself should also be thoroughly ventilated.

I will now briefly state how a house might be built so as to be efficiently ventilated on the principle of thermo-ventilation.

It will be sufficient to take one room as a type of the rest, and I will assume that it is desirable to keep up the old-fashioned open fireplace, wasteful as it is.

The fresh air may be brought directly through the outer walls as in sketch B, or may be first slightly heated by passing through a hot water coil, or other apparatus.

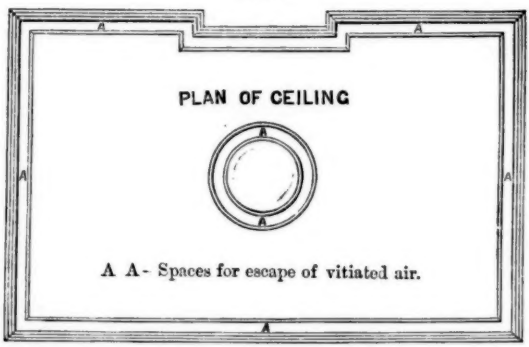
If the former course be followed, air bricks must be inserted in the outer face of the walls communicating with a channel running round a portion or the whole of the room.

If warmed air is desired it must be brought into the channel through tubes in the wall.

The inner channel should be formed by a cast-iron box, with an ornamental openwork front, and without a back. The front, which may be of brass, should be fastened so as to be readily removable. The fine wire gauze screen being fixed as shown in Fig. 2.

The exit for foul air should be through open work in the ceiling, as shown in Figs. 4,

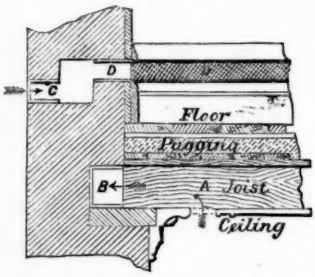
Fig. 4.



5 & 6. This openwork might either be done in plaster similar to the centre ornament, or fine brass wire gauze might be inserted in the cornice. The foul air would pass through this into the spaces between the joists, when the sound boarding and pugging will prevent its ascending into the upper rooms. From these spaces it would pass into a cast-iron channel running round the room, which would communicate with the chimney or air flue, or in some cases directly with the outer air. The openings into the chimney or air flue must be fitted with valves, as before.

I believe it would be easy to construct a chimney having all the advantages of a chimney and air flue combined.

FIG. 5.—SECTION.



A tube should be inserted in the brick trimmer giving immediate communication with the fire above, which, when lighted, would aid the ventilation of the lower room.

All large houses should have a special ventilating shaft, communicating by means of pipes and valves with every room in the house. If thermo-ventilation alone is intended, a fire must be kept burning at the base of the chimney, the only supply of air to which must come through the tubes.

Some day, perhaps, we may have ventilating shafts for every street or block of houses. We provide for the carrying away of foul water, why not of foul air? The one is just as harmful as the other. Perhaps, too, though this belongs rather to warming than ventilation, we may some day see but one fire to each house, and even one chimney. Nay I will go further, perhaps one chimney to a great number of houses, perhaps even one to a town! This may seem a speculative flight; but had coals been very dear instead of cheap, I feel sure our present wasteful system would not have lasted long.

Before quitting the subject of house ventilation, I will notice one fruitful source of annoyance, which is often closely connected with defective ventilation, I mean

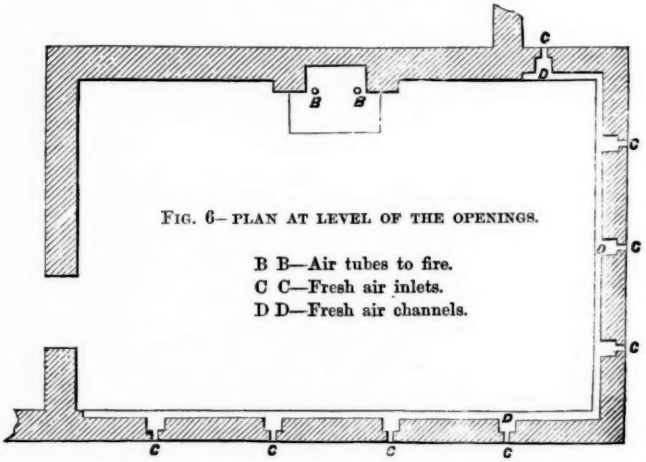


FIG. 6—PLAN AT LEVEL OF THE OPENINGS.

B B—Air tubes to fire.
C C—Fresh air inlets.
D D—Fresh air channels.

smoky chimneys. Want of air causes perhaps more chimneys to smoke than any thing else, and before any one sets to work to alter the chimney in any respect, it is better to see whether it is not more air that is wanted. This may be easily done by trying the fire with a door or window open, and with the same shut. If in the latter case the fire smokes, while in the former it does not, then want of air is the cause. Care must, however, be taken, as to what window is open, as gusts of wind or a cross draught will often cause the fire to smoke.

For churches, schools and factories, thermo-ventilation may be used, but probably the fan, or blowing wheel, will, in many cases, be more efficient and economical.

I believe it is in use in some buildings in London with very satisfactory results.

Its useful effects will vary with the size of the wheel and the speed at which it is driven, and in designing a fan it should

be borne in mind, that a large fan and low speed is generally better than a small one and high speed, chiefly on account of the vibration caused by gearing running at great velocities. The motive power may be either steam, water, or a weight which can be wound up as occasion may require.

It is impossible here to even refer to many noxious manufactures, chemical and otherwise. But of this we may be sure, that if they are prevented by law from polluting the atmosphere, the science of chemistry is quite equal to finding a remedy, and even to converting the noxious fumes into useful products.

There is an objection to thermo-ventilation, which does not apply to the fan, viz., that, as it usually depends for action upon the difference in temperature between the inner and outer airs, so in summer it may come to a stop, or be even reversed.

This objection is not of much weight, as people are far oftener out in the air in summer, and at night when gas or candles are lighted ventilation would commence again.

A special shaft would preserve the action constant all the year round, though most active in winter.

The fan is probably the leading instrument in mechanical ventilation.

Box states that a fan 5 ft. in diameter running at a speed of 50 revolutions per minute will discharge 2,250 cubic ft. of air in that time, while a fan of 10 ft. diameter at 25 revolutions per minute will discharge 9,000 cubic ft.

The third case I mentioned above was that of sewers. It may be considered established that the exhalations from fresh sewage are not injurious, but it is equally sure that those from putrid sewage are highly poisonous. Of all of them sulphuretted hydrogen may be fairly considered the most deadly. This gas is slightly heavier than air, hence it is more difficult to remove than the lighter gases.

According to Thénard, a proportion of $\frac{1}{1500}$ of sulphuretted hydrogen in the air will kill a bird, $\frac{1}{1000}$ a dog, and $\frac{1}{250}$ a horse.

Some of the gases generated in sewers are explosive when mixed with the atmosphere, hence it would be dangerous to introduce them into factory chimneys. The experiment was tried in Southwark with the blowing up of the furnace as the result. With sewers, as in other cases, ventilation must be subject to modifications.

In villages and small towns where pipe sewers are alone employed, small ventilating shafts carried up the nearest building, tree, or other suitable object, will answer the purpose, viz., that of relieving the sewers of any pressure of gas.

Their useful effect will be increased by the Archimedean screw cap as used in Liverpool, and a wire basket containing charcoal may be beneficially placed when the gas must pass through it.

Large brick sewers must not only be relieved of pressure, but must be clear enough for men to work in them.

In London we all know how they are supposed to be kept clear of foul gas, that is by the numerous open gratings which are seen in every street.

This would seem at first sight a rude method and a dangerous one. Experience, however, teaches us that the evils naturally to be expected from such a system are not so serious in practice as the nature of sewer gases would lead us to think. No doubt the diffusive property of gases has much to do with this favorable result. By the proper use of charcoal it is stated that the possible evil is reduced to a minimum.

I do not think any inseparable difficulty would be encountered in applying mechanical ventilation to sewers. Certainly there is the cost, but this should not stand in the way for a moment where the public health is concerned. Let those in authority say it must be done, and I feel sure the way would soon be found.

A sewer 6 ft. in diameter and five miles long will contain 746,000 cubic ft. of air, but after deducting one-third for space occupied by sewage water, 497,550 cubic ft. would be the quantity left to be dealt with. As mentioned above, a fan 10 ft. in diameter will remove 9,000 cubic ft. of air per minute, so that the entire quantity in the sewer might be changed once every 56 minutes. Certainly nothing like this would be required.

Practical difficulties would, no doubt, be encountered, especially in regulating the admission of air into the sewers, the position of the fan, the construction of side entrances, gullies, etc.; but these difficulties must be encountered and overcome if we wish to apply mechanical ventilation to the sewers of London. I am aware that there

is nothing new in this proposed method of ventilating sewers, as it was suggested by Mr. Gibbs, I believe in 1871, when it was met by objections that unless every gully or air hole were stopped up when the fan was at work, the air would enter the sewers at the nearest inlet with great velocity, which would diminish the further the distance was from the fan.

I think, however, it is not beyond the engineering talent of the country to devise inlets which shall admit the air to sewers in such proportions and at such places as may be required.

The difficulty would be much diminished if a system of sewers had but one or two outlets; and if the sewers were used simply for sewage and not for surface and subsoil water, the difficulty would be very small indeed.

The same objections will, moreover, apply to any system of artificial ventilation for sewers, whether it be by the furnace or by simple ventilating shafts.

The following table, compiled by Mr. Haywood, C. E., showing the temperature of the City sewers, will not, I think, be out of place:—

Time of Year.	External Temperature in Shade.			Temperature in Sewer.			Above External Temperature.	Below External Temperature.
	Highest.	Lowest.	Mean.	High.	Low.	Mean.		
Summer	72°	55	65.04	68	56	61.92	....	3.12
Winter	34	30	32 37	52	40	43 98	11.61	.... ..
Spring	61	46	52.46	59	48	52.52	0 06	.....
Autumn	68	48	59.90	70	53	62.97	3 07	.....
Average of year	.....	.....	50.24	.....	. .....	55.35	5 11	.....

The table shows us we cannot at all seasons rely on the superior temperature of the sewers for ventilation.

The last part of my subject presents fewer difficulties, I think, than the sewers.

No description of the way in which underground railways are now ventilated need be entered into.

We are all acquainted with the stifling atmosphere underground, and the choking, burning-matches odor which pervades the stations and streets near them. The insertion of iron grids in the roofs of the tunnels and the discharge of the noxious vapor and steam into the streets can hardly be considered a satisfactory solution of the question.

I believe we must here call mechanical ventilation to our aid. But first, let us consider the condition of the structure we are going to treat.

Taking one of the metropolitan railways as a type, we see it consists of a series of tunnels, and open or semi-open stations. The foul air is generated chiefly during the passage of trains through the tunnels, and a certain quantity of this foul air is thrust into the station by the train as it enters the further end of the tunnel. This foul air, being heated, slowly ascends, filling the streets and neighboring houses.

The stations are nothing more than dwarf ventilating shafts in which the passengers are partially stifled previous to the completion of the process in the tunnel.

Having stated the conditions of the structure, let us consider what is required to be done.

First, we have a certain quantity of foul air to get rid of without harm or annoyance to the public. Secondly, the stations must be kept so clear as to allow of passengers using them with comfort. And thirdly, circulation of air should be maintained in the tunnels, which should be kept as sweet as possible, not only for the sake of the passengers, but for the workmen also, and for the greater security of the public against accidents.

It seems to me that these objects will be best accomplished by reversing the present system, turning the stations into downcast shafts, and drawing the foul air away at the middle of the tunnels.

A little consideration will show how a series of tunnels might be connected together by what might be called air sewers, and the foul gases led to one or more pumping stations, there to be forced up high chimneys.

The pumps might be either air pumps, such as are I believe used in some Belgian

collieries, or machinery similar to Nixon's ventilator, or one of the many kinds of fan.

Some of these machines are very powerful. At the navigation pit, near Aberdare, Mr. Smyth gives the theoretical quantity of air expelled per minute, by one of Nixon's machines, at 166,000 cubic ft. In Belgium many fans of enormous power are at work ventilating coal mines.

The chief difficulty is the expense, but I submit this ought not reasonably to stand in the way.

I believe, however, that a plan could be found, which would accomplish the object at no very extravagant outlay.

I have said nothing about ventilating ordinary railway stations,—first, because it is difficult, if not impossible, to apply any system to a building which sometimes consists of but one wall, and a part of a roof; and secondly, when the station is of greater pretention, it is almost always open at both ends, and has usually a great deal too much air in it already.

Free escape for steam must be provided, and I think a good example of roof for this purpose was shown, to those of the members who visited the Great Eastern Railway extension works, on Friday last, at the low level station at Shoreditch.

In conclusion, I would again insist on the deep importance of the subject especially to Engineers and Architects. The limits of my space, not to mention other causes, have, I am well aware, prevented justice being done to it; but the object of a paper like this, is more to put forward sound principles and throw out ideas, which may when opportunity requires be worked out to good purpose, than to lay down schemes to meet every or any particular case.

Since the foregoing paper was read before the Society of Civil and Mechanical Engineers it has been suggested that, with some additions, it would form a pamphlet, useful to more general readers than those for whom it was originally intended. All scientific men acknowledge the necessity of ventilating dwelling-houses and buildings such as are mentioned in the paper, but with the general public it is unfortunately far otherwise, and one of the greatest difficulties to be encountered in the progress towards a complete and perfect sanitary condition is this inertia of those most interested. Difficulties are, however, only made to be overcome, and it is in the hope of doing something, however little, towards overcoming this particular difficulty that I venture to trespass further on the patience of the reader, and I propose to confine these remarks to the sanitary condition of our houses as being the subject of most immediate importance to the general public, for ventilation of such structures as factories, railway tunnels, and sewers, though of great moment, must be left in the hands of the Engineer who designs them, each case being treated upon its own merits and with due regard to its peculiarities. All the public can do in such instances is to insist that there shall be ventilation of some sort.

All persons readily admit as a truism, that they cannot live without air, but, unfortunately, they seldom get much beyond the bare admission. Air is not treated by them as a substance requiring space as solids or liquids do, and means of passage into, or out of, rooms, churches, etc., just as much as water requires pipes or channels to allow it to flow into or out of reservoirs. With most persons air seems to be an abstract idea rather than a substance of vital consequence to the whole living creation.

I have stated in the paper that air, which has once passed through the lungs is unfit to be respired again, just as unfit as any other substance which has once passed through the system is to be used, as it were, over again. So that, were there no other source of contamination to the air of a building, ventilation would be rendered necessary by the very presence of living beings. As it is, however, there are so many other evil influences at work in most houses and other buildings that the necessity is made far more absolute.

It is usually only in times of panic, caused by the approach or presence of some fearful epidemic, or of a calamity such as last year threatened this nation, that people seriously turn their attention to sanitary matters, and at times like these they accept the wildest schemes and act upon the crudest notions until, finding matters are no better, and perhaps rather worse than before, and the fright beginning to wear off, they relapse into carelessness, and vote sanitary science all nonsense. I think defective education is responsible for a great deal of this. I do not intend to assert that the generality of people, at any rate in the upper and middle classes, are what is commonly called ignorant; probably

most of those who would be willing to turn their attention to sanitary matters, not being professionally engaged in them, have had at least the usual amount of education, as the term is commonly understood. The three R's are familiar to them as are also mathematics, Greek, and Latin, and they can probably converse in one or more of the modern languages, but what may be called the science of living, *i.e.*, how life is sustained, and the reasons why sanitary matters should be so carefully attended to in order that health and strength may be insured, are things of which comparatively few know anything at all.

In this paper I wish to impress upon the reader the very great importance of pure air to the human body, and to show how such air, or as pure as the district affords, may be insured in our houses.

It has been stated before, that one of the elements of the atmosphere unites in our bodies with certain of the elements composing the food we eat. This union of elements is a true combustion, though a slow one, as true and real as the combustion of coals in a fire grate.

Our food, having been decomposed in the body, is brought into a state proper for sustaining life and animal heat in us when, as venous blood, it is submitted to the purifying action of oxygen brought into the body by the lungs. Without the element, oxygen, which I have before stated forms part of the atmosphere, this purification could never take place, for the other gases have no power of the kind. It will be obvious upon consideration that if a portion of oxygen in the air we have breathed has united with elements composing our food, that portion is removed from the atmosphere and must be replaced if breathing is to be continued.

I will here explain for the benefit of persons who may be wholly unacquainted with chemistry, what is meant by the term "element." The ancients held that there were four elements, or simple bodies, viz., earth, air, fire and water, but the progress of chemical knowledge soon revealed the fact that these were not elementary bodies at all, three of them being compound, while the fourth, fire, may be more properly described as a condition of matter. An element is a body which cannot, as far as we know, be divided or decomposed. It is unalterable and indestructible, and is therefore called a simple body or element.

Elements, however, combine with one another, and lose their individuality, so to speak, in the compound. Thus two simple bodies, gases, hydrogen and oxygen, unite in certain definite proportions and form water; but the water can be again decomposed into its constituents.

Air, although I have called it a compound, is not, chemically speaking, strictly so; it is a mixture of gases which preserve their individuality as sand and sugar would do if they were mixed in a vessel.

We are at present acquainted with more than sixty elements or simple bodies.

But to return to the atmosphere. It must not be imagined that we remove all the oxygen from the air we breathe; on the contrary, the removal of a small percentage renders air incapable of supporting life, and a still less diminution causes the difference between fresh air and vitiated.

I have said a good deal about the effect which the act of breathing has upon the atmosphere, because I want to make very clear the fact that the same air should not be respired more than once, and that it cannot be so, even in part, without danger to health. The other results of respiration, viz., carbonic acid and water, have been mentioned before, and it was shown that they contributed to foul the air.

I think we may, without serious error, divide noxious gases into two classes, placing those which are negatively poisonous in one class, and those which are positively, or actively, so in the other. To the former belong—as types—carbonic acid and nitrogen, both of which, though not in themselves injurious, are incapable of supporting life; so that an atmosphere composed wholly of these gases, or containing them in undue proportion, is fatal, from its negative qualities, to living beings. Carbonic acid gas, as before explained, is one of the products of combustion and respiration, while nitrogen forms 79 per cent. of the volume of the atmosphere. Its negative qualities are there, however, counterbalanced by the presence of oxygen.

With gases of the second class the case is very different. Some of them—such, for instance, as sulphuretted hydrogen and carbonic oxide—are fearfully active poisons. The former exists in putrid eggs, and some other animal and vegetable matters; also in certain waters, called *hepathic*, such as those of Harrowgate. It is usually formed in the putrefaction of vegetable and animal

matters; hence it is found in sewers, and especially in cesspools and similar places where accumulations of this filth take place. During the emptying of such receptacles, workmen sometimes suffer from asphyxia, or, as the French call it, "*le plomb*" (probably from the oppression on the chest which accompanies it). Parent Duchatelet states that the symptoms of poisoning by sulphuretted hydrogen are very alarming, for "the individual is either seized suddenly, and dies instantly, or, if the quantity of deleterious gas is too little to bring instant death, the asphyxiated person, suddenly losing consciousness, is taken with convulsive movements or other very grave nervous disturbances, and it is only after several days that he recovers perfect health." The presence of sulphuretted hydrogen is readily detected by its odor, which resembles that of rotten eggs; but it is soothing in its nature if inhaled, which renders it especially dangerous when escaping into rooms where persons are sleeping.

It will be seen, then, of what extreme importance is the prevention of the passage of sewer gases into our houses, and I have entered somewhat fully into the properties of these foul gases, because I wish to show clearly that they are not things to be trifled with.

Carbonic oxide is, like carbonic acid, a product of the combustion of carbon, or the union of carbon with oxygen, but the proportion of oxygen is less in the former than in the latter compound. Carbonic oxide, though a dangerous gas, need not be considered at length here, as it does not, I believe, exist in sewers, and is very seldom found in houses. It cannot, like sulphuretted hydrogen, be detected by its smell, as it is inodorous as well as colorless and tasteless. Carbonic oxide burns with a blue flame, which probably most people have noticed at some time or other, either playing over burning charcoal or dancing upon an ignited lime kiln.

I must now leave this part of the subject and say a few words useful, I hope, to those who are about to choose a house, whether as tenants or purchasers, and in doing so I may, perhaps, travel somewhat away from ventilation.

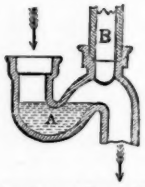
The first consideration, after settling which town or part of the country it is desired to live in, should be the situation of the house, *i.e.*, not only its aspect, but the condition of the soil on which it stands, and its position with regard to any ponds, streams, rivers, or other natural features.

Taking first the aspect. It is generally considered that a house is most favorably situated when its principal front is towards the south-east, for it then gets the morning sun, while the rooms are sheltered to a great extent from the midday heat. The south-west is the rainy quarter in the country, and should, therefore be avoided. A gravel soil is commonly to be preferred to any other, although, I believe, that in towns which are well sewered and drained, the nature of the soil is not of so much importance; indeed, one might readily imagine a case in which a gravel soil would be anything but a benefit—as, for instance, where there is a pond near the house, and on about the same level, or in towns where percolating cesspools are the fashion. Running water near a house is not objectionable, indeed many persons consider it rather beneficial than otherwise; but before taking the house, care should be exercised in ascertaining that the water is free from sewage contamination, especially if it be a small stream, or liable to dry up in summer. Stagnant ponds should always be avoided, especially if the house is on nearly the same level.

With regard to artificial sanitary conditions, as distinguished from natural situation, soil, etc., the first question to be asked of the landlord should be as to a good water supply to the house other than from wells on the premises. There being no such supply, nor means of laying one on, would certainly be against the house, inasmuch as where there are no water works, there is generally no system of sewerage, and it may safely be said that in any unsewered town there is hardly a well the water of which is fit to drink; to say nothing of the labor of pumping water into cisterns, etc. From this follows, naturally, the question as to the sewerage of the town or village. If there is no system of sewers, I would say, "live anywhere else if you possibly can," for the absence of sewerage indicates the existence of some form of cesspool, an evil so great that nothing but absolute necessity should cause any person to take a house to which a cesspool is attached. I say "some form of cesspool," for I am quite aware that there are schemes which profess to do away with water-closets, and cesspools, and partially with sewers, but upon examination, they will all be found

wanting in some material point. Among these plans are the "dry earth" and "pail" systems, both, in my opinion, but forms of cesspools. If the town or village is sewered, the first point is to make sure that the house drains are properly connected with the sewers. It is no uncommon thing for the drain to be carried from the house to the outside of the sewer, and to stop then, being thus rather worse than useless. The bricklayer would probably call this "leaving another job." After seeing that the connection is properly made, *i. e.*, that the pipe really passes into the sewer, the next thing to be done is to find out of what the house drain is made, or how it is laid. These points I have alluded to before, and shall therefore pass them over here. Next, make sure that the house drains are properly ventilated. The landlord or builder will probably tell you that they are "trapped" and that no foul gas can pass the trap. This is a great delusion, and should not be listened to for a moment. The trap is a very useful and necessary thing, but it must not be expected to do more than it can, and in order to make this clear, I will explain what the common siphon trap is, viz., a bent pipe generally of the form shown in section in the sketch.

FIG. 7.



The common trap has not the ventilating pipe B.

These pipes always retain a certain quantity of water (indicated by shading in the figure) when in use, in the dip or bend. It will be observed that the upper part of the pipe dips into the water which completely fills the bend, and the water is sometimes said to "seal" the trap, and it is assumed that it will entirely prevent any gases from passing into the house. A little consideration will show, however, that if the gas is generated in such quantities as to cause any considerable pressure in the sewers, it will readily pass through the water into the house. That this has actually happened, the following incident recorded by Dr. Carpenter will show. The ventilating pipe spoken of was in fact doing duty as a water-pipe from the cistern! "On the night of October 17th I was aroused by a loud noise proceding from the closet; it continued at intervals throughout the next day. Unable at first to account for it, I eventually found that it was caused by the ventilating pipe doing duty as water-pipe to the overflowing cistern (during a very heavy rainfall). There was no room for exit of foul air from the sewer, which, therefore, was forced through the trap of the water-closet, with, at times, the force of steam through the safety-valve of a steam-engine. The nuisance continued for nearly three days before the weather would allow the plumber to rectify a mistake which had been committed in the previous summer, the mistake of making the ventilating-pipe do duty for a water-pipe." Dr. Carpenter then says that owing to there being no particular smell, this escape was tolerated, but in two or three days the occupants of the house were attacked by typhoid fever, and that in many other parts of the town enteric disease appeared at the same time.

The traps should be ventilated, and the ventilating pipe should *not* open into the house. I know no better means of ventilating the traps than that I have before described, and as shown in the figure above. In this A is the trap and B the ventilating pipe, the arrows indicate the direction of the flow of sewage from the house to the sewers. It will be obvious that if any accumulation of gas takes place in the sewers, it will pass up the ventilating pipe B, instead of forcing the trap and flowing into the house. Therefore, insist on the drains being ventilated, or do not take the house.

There are several kinds of trap, but the principle of all is nearly the same.

Having settled these preliminaries, let us consider the house itself, and examine it carefully.

I need hardly say that this can scarcely be done satisfactorily by the intending tenant or purchaser, unless he has a far greater knowledge of building and sanitary matters than falls to the lot of most non-professional men, but much may be accomplished by the diligent use of eyes, and nose especially, if they are used in the right way.

The foundations and basement may reasonably claim attention first. Under all the walls there should be a mass of good

concrete, and the whole area on which the house stands should be covered with the same in a layer, not less than 6 in. thick. This layer of concrete, if made with good hydraulic lime, or better still, Portland cement, will not only prevent damp from rising into the house, but will keep out those domestic pests, rats, mice, and black-beetles as well. In all damp soils concrete under all basement floors should be insisted upon. If it is not there, and the landlord will not put it, do not take the house.

Next, note the thickness of the walls. If any external brick wall is less than 14 in. thick, the house will always be damp and uncomfortable. Examine the water-closets, especially as to position. I have already entered into this question, and will not therefore say any more about it here. Look to the water cisterns, and find out where the waste pipes go to. If into the soil pipe of the water-closet, or into the drain, as is commonly the case, have them altered at once. Dr. Carpenter's experience will give a reason for this. Both rain-water pipes and waste-pipes from the cisterns should not run directly into the drain, but should have their ends visible outside the house, and above the ground. Under each of these pipes there should be a trapped sink, connected either with the house drains, or, in certain cases, with separate ones. By the regulations made under "The Metropolis Water Act, 1871," in all parts of the Metropolis where the Water Companies give a constant supply of water, the waste pipes from all cisterns are to be converted into warning pipes, and the outlets of such pipes are to be so placed that the officers of the Companies can readily ascertain when water is flowing from them. This regulation is intended to prevent unnecessary waste of water.

Lastly, the rooms must be considered. They should, if possible, be both light and lofty; for, low, dark rooms are depressing and unhealthy, and should therefore be avoided. All the rooms, without exception, should be efficiently ventilated, not by open windows or doors alone, since, for full half the year, an open window is impossible in England, but by some plan which shall be independent of both, for we cannot, unfortunately, suspend our breathing whenever it is necessary to close door and window, although the majority of house builders seem, if one may judge from their works, to think it the most common-place operation in nature.

An instance of this want of forethought lately came within my knowledge. Some persons who were interested in the establishment of a particular trade in the metropolis, built a small factory for the purpose, and, as usual, ventilation was left to chance. The number of persons employed, however, brought the firm under the "Factories Act," and the Inspector insisted that ventilation should be provided. The owners, being in a difficulty, sent for a carpenter and joiner, as the most likely person to help them out of it; he naturally recommended the execution of sundry carpenter and joiner's work, and proceeded to make all the windows to open, which up to that time had been, very properly, fixed. The immediate result of this was that half the persons employed caught violent colds, and the ventilation was quite a failure, for the next time the Inspector called, being a wet, windy day, all the windows were closed, and he, not unnaturally, concluding that nothing had been done, preremptorily called upon the owners to remedy the insalubrious state of affairs. They again called the carpenter to their aid, who, resolving this time either to kill or cure, cut a large square hole in the ceiling and roof and put up a kind of lantern, with louvre board sides, over it. Probably he intended this for an exit, but having made no provision for the inlet, the cold air came down upon the heads of those who sat below quite as fast as any foul air went out.

There is nothing more injurious than want of ventilation, except perhaps a draught of cold air. Proper ventilation should never cause draught.

Intending tenants will do well to get the necessary sanitary conditions complied with, before they enter into possession. Some landlords will promise great things before the tenant is actually in the house, but after that will do nothing whatever, and the unfortunate occupier finds himself obliged, either to make alterations at his own expense, put up with annoyance, ill health, and, may be, the death of some of his family, or, at great inconvenience, leave the house, and, perhaps, risk an action at law with the landlord.

If the landlord decline to make the necessary alterations before the tenant enters into possession, have nothing to do with the house.

To the case of inhabited houses, where ventilation or other sanitary matters are defective, most of what has gone before will apply. I would urge all persons not to allow defects in drainage or ventilation to exist an hour longer than is absolutely necessary. How many outbreaks of cholera can be traced to a defective drain or foul cesspool, and people have said "Oh, it is in the air," or in this, or in that, while the real cause was, perhaps, under their very feet.

With regard to country houses, which, from their isolated position, are beyond the reach of a system of sewerage, it must be admitted that many difficulties are presented to us.

Sewage must be disposed of by irrigation on the land, for there is no other successful method of dealing with it at present known, and therefore towns and villages have been empowered by various Acts of Parliament to acquire land for this purpose. Private persons have not this advantage and in their case the cesspool has always, until lately, been regarded as the only resource. But it is a very dangerous resource. Ask how the liquid gets away from the cesspool and you will probably be told that it percolates through the brickwork forming the sides, the bricks being laid dry on purpose, and passes into the surrounding soil. Yes, percolates under our houses, into the springs, pollutes the wells, until, as at Rugby before the sewerage works were executed, things come to such a pass that the fluid thrown into the cesspool in the morning is pumped from the well at night! Or, perhaps, the cesspool is well built and the sewage retained in it, but the mass of putrid filth must be taken away, and I suppose many persons have been disgusted at some time or other with this sickening process.

The remedy is not hard to find, but the means to be adopted will depend greatly upon the conditions of each individual case. Moreover, this belongs to another branch of sanitary science, and I am wandering away from ventilation.

What has been said with respect to ventilating drains connected with sewers will apply with more force where there are cesspools. For in the former case there may be no evolution of foul and dangerous gases even for years, while in the latter it is certain and continuous.

It is of no use to try and enclose it in the cesspool, free vent must be given if you would keep death and disease out of your houses.

In concluding these somewhat disjointed observations on a very important subject, I would ask the reader to remember that the whole paper has been written at different times, when a few moments could be spared from more pressing matters, and if I have not adhered strictly to ventilation, pure and simple; yet drainage and warming are so intimately connected with it, that it is difficult to treat of one without drawing in the others also.

Very much more might have been said about ventilating public buildings, such as churches for instance, where no attempt seems ever made to get fresh air in, or foul gas out of the building, but I have simply endeavored to convey a little useful information to the reader, which will, I hope, be of service in improving domestic comfort, and keeping disease away from our homes.

THE UTILIZATION OF SLAG.

By Mr. CHARLES WOOD.

From "Journal of the Iron and Steel Institute."

The enormous output of slag or refuse from blast furnaces in proportion to their yield of pig iron has always been one of the serious difficulties of the iron trade, and to the disposal of this refuse the attention of blast furnace engineers has been increasingly directed. In Wales and Staffordshire large tracts of land have been devoted to deposit, and huge hills of lava mark the buried greensward, the play places of former days.

The necessity thus indicated has come to Cleveland also; the waste lands are nearly filled up; the demand for slag is limited. The plan of sending it to sea, though good and workable, is costly, and so it comes that out of the struggle, a mode of converting a trouble into a gain, a difficulty into a profit, is the subject of this short paper to which I ask your attention.

The question of utilizing slag has from time to time occupied the attention of our

most able engineers, notably that of our valued ex-president, Mr. Bessemer, and from the time of his investigations and experiments from the year 1854 down to the present date, the patent records make honorable mention of a long list of worthy pioneers, in the rough road towards slag conversion.

More recently, Messrs. Smeeton and Bowler, Messrs. Bodmer and Wilson, Mr. John Gjers, Mr. Lurmann, Mr. Thomas Bell, and Mr. D. Joy, have each and all done good service, the two latter gentlemen especially.

In 1871, Mr. Joy submited to the iron trade of Cleveland a plan for shipping slag in blocks, differing somewhat from a plan proposed by the writer a year previous, to the Tees Conservancy Commissioners, for taking the slag to their breakwater; but also one for removing it direct from the furnace, in detail, by an endless band, variously applied and covered, and simultaneously with this, a similar plan was projected by Mr. Thomas Bell, and soon after practically worked at Walker.

The whole question became one of serious moment, and many minds being directed to the same point, numberless schemes were proposed. Mr. David Joy patented several forms of wheels, upon which he fixed cast iron trays or troughs, or, more properly speaking, chills for the cooling and disintegration of slag, and my own patent for a horizontal disintegrator was perfected and set to work. But the matter did not rest here; the more I went into the question the more evident it became that by disintegration slag could be made of much value. Experiments proved this, and the vertical granulator or sand-making machine, somewhat resembling one of the forms included in Mr. Joy's specification, but divested of the chills or troughs, and having the sides partially closed in, very similar to the rotatory puddler shown in end section yesterday by Dr. Siemens, is the latest, and I by no means say the last result. And it is to draw your attention in the simplest and briefest manner to the products of these two machines and their uses, that I venture to make these few remarks.

My first machine receives the slag on a horizontal rotative table; this table is composed of thick slabs of iron. These slabs are kept cool by a circulation of water through them. The machine revolves very slowly. The liquid slag flows upon the table and forms its own thickness, varying from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. As soon as the slag has parted with sufficient heat so as to become solid, water is allowed to run freely upon the surface, and by the time it arrives at the scrapers, it is sufficiently cool to part from the table freely and break up, and then drops into the wagons.

The slag sand machine is just the opposite in principle to the first-named machine. As the whole body of liquid slag runs from the furnace it flows directly into a deep bath of water. This water is kept in a violent state of agitation, and the liquid slag is instantly scattered in the body of water in the shape of sand, the water taking up the heat and throwing it off again in the shape of steam. Specimens of slag sand, and of the first mentioned machine slag, are upon the table for inspection.

The slag sand machine is made in a shape not unlike a rotatory puddler, only having sides, to enable it to contain from 2 ft. 6 in. to 3 ft. of water in the bottom. This cylinder is kept in motion by a small steam engine. The water is agitated by means of a certain number of buckets, placed in the inside of the periphery. These buckets are perforated, so as to act as screens, to separate the sand from the water; they also elevate the sand to the top of the machine, where it drops into a spout, and thence into wagons. The speed of the machine is about 180 ft. per min., or about $4\frac{1}{2}$ or 5 revolutions, according to the nature of the slag. Thus, the water is always in a state of rushing towards the bottom, and, meeting with the screens or floats, it rolls over in a violent manner. Into this water the slag is allowed to run direct from the furnace. The water acts upon the stream of slag by scattering it, as it were, and the action is so perfect that no crust, or any pieces larger than those shown, is allowed to form. On the table will be seen a large quantity of this slag, just as it comes out of the machine. The action of the machine is perfect, delivering the slag in a constant stream into wooden railway trucks, fit to be sent or dealt with in any way.

We now come to consider the way in which we can best utilize this slag sand. Mr. Bodmer, in a paper read before your Institute last year, stated that by mixing eight parts of granulated slag with one of cement, he could produce a valuable brick. At his request I sent him some of this sand,

and I have great pleasure in showing you bricks made from this material. By his process the sand requires no further manipulation than the mixing with lime and compressing in a hydraulic press, when, after two or three weeks exposure to the air, they are fit for use. The advantages and economy of this material are manifest, and these must, from their great cheapness, displace millions of bricks made on the old plan of burning.

We now come to consider the use of this material, as a substitute for sand, for building purposes.

You will see, from the specimens exhibited, which have been made a fortnight or three weeks, that mortar made from this sand, mixed in the proportion of one part lime to five parts of sand, when ground up together, is nearly equal to cement. If a small portion of ironstone be added, equal to about 5 per cent., this material increases its strength. I have also great faith that this slag sand, produced, as it can be, at the same, or little more than the present cost of running into balls, will produce a material which will be very valuable to farmers, containing, as it does, from 30 to 35 per cent. of lime, 38 per cent. of silica, and 3 per cent. of sulphide of calcium. Its light and porous nature, in opening and lightening up the land, will also be of great service.

I exhibit also some concrete blocks, made with a combination of my first patent slag, and the second, or slag sand, suitable for foundations of all descriptions, and even for walling for cottages. This material is composed of six parts of machine slag, from the first patent, and one part of the mortar, which, as I before stated, is composed of five parts of slag, with one part of lime, well ground up. These have all been mixed together, and formed into a block, as shown. That of a red color has one part of ironstone, one lime, and twelve parts of slag. It has been made now about three weeks, and, I think you will admit, there are few cement concretes equal to it for strength; and the remarkably cheap rate at which it can be produced must render it invaluable for many purposes. I, myself, should not hesitate in using it under the heaviest buildings or machinery.

There are, also, specimens of the first patent machine slag, made into concrete with cement, as used very largely by the drainage contractors in Middlesbrough. This piece was taken out of the sewer, after it had been in some two or three months; it is made with Portland cement.

Although bricks that are exhibited with Mr. Bodmer's name upon them have been, I believe, made with about one part of cement to eight parts of slag sand from my machine, those of rougher quality, made by myself, in an experimental die, contain from twelve to fourteen parts of slag sand to one of lime.

There are several uses besides those mentioned, to which the slag sand can be put, such as the pig beds, as employed by Mr. Gjers, garden walks, asphalt, and I look forward to no distant date when the railways will employ but little else for the top dressing, or top ballast for the sleepers.

I have only one more remark to make before concluding. I think I have proved beyond a doubt that slag can be utilized, and that it can be put into the market at a very low price, compared with other materials, and that it contains very valuable chemical combinations, different from any other. With these facts before me, I do not see why hundreds of thousands of tons each year should not be made use of; and that, as this, mostly, must be put into railway trucks for transport, it may become as much a source of revenue to railways, as the carrying of pig iron, or other produce, and thus again be made to produce a useful effect.

COST OF MAKING SLAG SAND.

Make of furnace, about ..... 25 tons iron.
Do. do. .... 36 " slag.

	s.	
One man per day.....	4	
8,000 gallons (water) at 3d..	2	per shift.
Wear of machine.....	3	

$9 \times 12 \div 36 = 3$d. per ton.

CONCRETE BLOCKS, PER CUBIC FOOT.

	s	d	
Rough machine slag, 8 tons.....	4	0	
Slag mortar..... 1 "	4	0	½
9 tons.... =	8	0	
Labor, 1s per ton.....	9	0	
	17	0 ÷ 9 = 1s. 11d.	

1s. 11d. per ton, or ¾d per cubic foot. If with ironstone, about 1d per cubic foot.

MORTAR FROM SLAG SAND.

	s.	d.		s.	d.
5 tons sand, at 3d.....	1	3			
1 ton lime, at 15s.....	15	0			
6	16	3 ÷ 6 =		2	8
Grinding.....				1	4
				4	0

Four shillings per ton.

BRICKS PER THOUSAND.

	s.	d.
2 tons 10 cwt., at 3d. per ton	0	7½
Lime	4	0
Wear of machine	1	3
Coals and water	1	0
Labor, etc	3	2
Per 1,000	10	6

ANALYSIS OF FURNACE SLAG.

Silica	38.25
Alumina	22.19
Lime	31.56
Magnesia	4.14
Protoxide of iron	1.09
Manganese	trace.
Calcic sulphide	2.95
	100.18

DISCUSSION.

Mr. Parks said a question of considerable importance had been suggested to him in connection with that subject—that was, that the slag of the blast furnace was by no means uniform in composition, and as some gentlemen present had probably tried it from various furnaces, and under various conditions, he would be glad to be informed whether it could be used in a basic condition as in making Bessemer iron or white iron, because it might differ very materially in its properties, according to the condition under which the furnace was working.

Mr. Homer had some time ago tried several experiments for the purpose of utilizing blast furnace slag, and he found that by mixing a portion of fire-clay slag and lime he got very good results from it. Two or three experiments were tried by different parties, and found to answer very well, and so far as utilizing slag as ballast for railways, he had tried it and it was found to answer admirably as ballast for railways.

The President inquired if he (Mr. Homer) ran it into water.

Mr. Homer replied that he did. He put a cistern near the bottom of the furnace and into that he ran the slag, and the slag going into water in that way caused it to form into a frothy condition, and when loaded up it made very good ballast. Then so far as regards utilizing it in the shape of bricks, he had some very fine specimens of bricks made from slag, but made in a different way to the first experiments. Underneath their clay-band iron stone they had got fire-clay, which contained 40 per cent of alumina. They had always had great difficulty in dealing with that alumina in making bricks, and as the bottom of the mine lifted up they found it entailed great cost upon them in maintaining their road, and he (Mr. Homer) had been very anxious to obtain some way of disposing of it to a profit in connection with the blast furnace slag. He had recently put up a clay machine in which he had a pan with a perforated bottom, and in that he put the fire-clay containing so large a percentage of alumina mixed with it; surface clay and the slag from the blast furnace he ground together, and it passed through a false bottom. It was then taken up by the elevator into a pan and mixed together, and from that they got a fine bastard brick, and a brick that would enable him to dispose of a very large quantity of blast furnace slag in such a way as to enable them to get rid at the same time of a lot of refuse, with which they were covering over acres of land as spoil, and he thought the thanks of that meeting were due to anyone who would give their attention to it the way Mr. Wood had done, because if they could succeed in utilizing blast furnace slag, it would greatly benefit his part of the country, North Staffordshire, where the land was getting covered over with it near to the furnaces.

Mr. Alforth asked Mr. Wood at what price per cubic yard he could produce the concrete, and the price per thousand bricks.

Mr. Snelus had given some attention to this matter, and he was now engaged in putting up a mill at West Cumberland to deal with the slag there, which, generally speaking, was highly basic, and at about this time (May) last year, he went to Germany, partly for the purpose of seeing Mr. Lurmann's process of utilizing the slag. He had seen there slag—from a furnace working Bessemer iron, and also from white forge iron—run into water, and he found that the slag produced from the furnace working on the Bessemer pig broke up into pieces much more easily than the other, as they would expect from the large quantity of sulphide of calcium present, and Mr. Lurmann considered it a much more valuable product than that which he obtained from the black cinders when the furnace was working on white iron. From such furnaces he considered that the slag was best utilized as ballast. Very large quantities of it were so used, but it could also be made into bricks. It required, however, a larger quantity of lime than the more basic slags, which, when mixed up with one-sixth of lime, was formed into

bricks by a steam press. The bricks were dried for some weeks, and he had seen several houses built of them, which had been built some two years. He tried his pen-knife upon them, and found the bricks remarkably hard, much harder than he would have expected. Yesterday, he had the pleasure of witnessing the making of bricks by Mr. Bodmer's process. He (Mr. Bodmer) used a hydraulic press instead of a steam press. The two processes were almost identical, at all events he did not see much difference, but Mr. Bodmer had certainly a much better mixing apparatus for producing the bricks, and they were of a better and finer quality than Mr. Lurmann had yet attained. He (Mr. Snelus) thought there was a very great future for those bricks, and that any apparatus that would enable them to get the slag into a state of sand cheaply, and with little trouble at the furnace, would be of great advantage, because that was the great thing. The great difficulty was to take the slag away from the blast furnace. They had very little room at blast furnaces to do any work, and as far as he (Mr. S.) could see, the simpler the process could be made the better, and running the slag into water seemed to him as simple a thing as they could possibly have. Running it into a deep well of water, and simply moving it by a Jacob's ladder, seemed to him to do all they required, and if the apparatus under review would do that at a cheaper rate, it would certainly be better. Any plan that would convert the slag into fine powder would certainly be of very great value.

Mr. Homer wished to say that after running the slag into water, the top part of the slag they could almost crush in their hands, as it took very little pressure to break it up.

Mr. Richardson having had a little experience in mixing Portland cement with slag, which was not perhaps quite what the paper intended to deal with, or to disclose, but as it had been of utility to him, it probably might be of utility to other members, and therefore he would give them the result. In their shops they had hard flagged floors, and there was a good deal of traffic over them on small wheels. The consequence was that they found the joints of the flags slipped and gave way, and made the floors very unequal and irregular. They then got a quantity of silicate of iron from the forge, having no puddling furnaces in the neighborhood, and tried to grind that under an edged roll to fine powder, and mixed it with very hard powdered cement, and made the floor in each shop about four inches thick with that material. It had then been working for two years, and had not shown the least failure under the greatest pressure that they could put upon it. In some of the staircases of the factories, where great numbers of people were continually going up and down, the steps had worn considerably, and to save the great expense of pulling out the old and putting in new steps, they had roughed them with a pick, and plastered them up with that film, by which means they made them quite strong, and he found that those steps were wearing much better than even the hardest stone that they had before. He mentioned that for the purpose of giving to anyone else similarity situated, the benefit of that little experience. He had found it a very valuable material, and almost indestructible in wear.

Mr. Maynard inquired what the thickness was.

Mr. Richardson replied, about one-fourth on the top, or about one-sixth for the bottom portion. Three inches of rough stuff was put in, and about one inch of very fine on top, and they put more Portland cement in that. The soft Portland cement was like soft brick, and did not do much good. It required to be burnt hard.

Mr. Wood, in reply, said he must confess with regard to the slags made from Bessemer iron he was rather at a loss to answer the question, but he thought Mr. Snelus had answered it pretty clearly. Of course everything of that sort would depend upon chemical combination—that was to say, whether it contained more or less lime or silica; accordingly as they had those two properties, so must they vary their cement and their pressure. With a little attention to those two points, he saw no reason whatever why they should not make as good—and quite as cheap—a concrete brick as the specimens they saw on the table. In reply to Mr. Alforth, as to the cost of making bricks and concrete, he had it upon the authority of Mr. Bodmer, who was making large quantities from the material produced by the sand slag machine, and from the lime which could be obtained in Middlesbrough now at 15s. per ton. Taking the cost of material—produced as

they were at such remarkably low rates and without profit—those bricks could be made for from 10s. to 12s. per thousand. For the concrete blocks they might take the machine slag at 6d., and the mortar at 4s. 0d., then it would be found that they could produce a cubic yard or a ton at 1s. 8d., which would be equal to about $\frac{3}{4}$d. per cubic foot without the ironstone, and about 1d. with the addition of the ironstone. Mortar fit for building houses, containing five of sand and one of lime, could be produced at 4s. per ton.

Mr. Whitwell would like to ask Mr. Wood if the ton of concrete occupied a cubic yard in the same way as the bricks did.

Mr. Wood said there was very little difference. They might roughly calculate a cubic yard as being about a ton weight, more or less. His experiments showed that.

The President, as a producer of blast furnace slag to the extent of about a thousand tons per day, would be very glad indeed to have an opportunity of applying it to a beneficial purpose, both on account of the public and on account of himself. With regard to the disintegrating of the slag, he did not quite follow the reasoning made use of by Mr. Wood. He (Mr. Wood) must remember that lime when used for agricultural purposes, was used under totally different circumstances and conditions to that where it existed in slag, where it was really in the form of a silicate. Believing, however, that such disintegrated slag might be usefully employed for land where it was somewhat heavy, he (the President) had had a large quantity, many tons, run into water and taken out producing exactly the same substance that he (Mr. Wood) had obtained, and applied it to land, and on comparing, as fairly as he could, the appearance of the vegetation, with and without the slag, he was sorry to say that he could perceive no kind of improvement from the application of it. In fact, he believed that as far as manure was concerned, they might as well use powdered bottles. He thought, however, that there semed to be a reasonable prospect of their being able beneficially to use a portion of the very large quantity of slag made in this country, and if, even in some districts, it should not be found quite as available as in the Middlesbrough district, where they made something like five millions of tons in a year, he (the President) thought there was a sufficiently large field of operations to entitle Mr. Wood to their thanks for the paper he had read before them.

THE WATER SUPPLY OF CONSTANTINOPLE.*

By HENRY A. HOMES.

In Eastern countries pure water is ever a theme of popular interest. The numerous "dry and thirsty lands where no water is," and the liability to droughts in more favorable positions, will always make the question of a supply of water of the utmost importance. The simple habits of the people, using no beverage in large quantity but water, render the matter of its abundance and quality, a fertile topic of conversation. The population that now inhabit Asia Minor and European Turkey, emigrating from a more arid country, retain as a hereditary gift an anxiety about, and a love for water, not because they need it more or use it more than other people, but because they appreciate it with more intense emotions. The records of the Bible are full of references to artificial arrangements for water by wells and cisterns, even for rural or nomadic tribes. The selection of the sites of the great cities of the old world of Asia has been controlled by their easy supply of water, such as Broosa, Cairo and Damascus. But when Constantinople was determined upon as the new capital of the Roman empire, the fact of its position as a place from whence to command two continents predominated over all considerations of an abundance of water. Before giving an account of its supplies of water, allow me to recall to your minds the prominent features of its geography.

Constantinople is built on the rocky heights of seven hills on the north shore of the Sea of Marmora, and just west of where the Bosphorus strait opens into that sea from the Black Sea. The distance between the Black Sea on the north and the Marmora on the south, is not more than twenty

* A Paper read before the Albany Institute, June, 4, 1872.

miles, for a distance of thirty miles from the Bosphorus towards the west. The general height of the table-land in the vicinity of Constantinople is about 150 to 200 ft., which is intersected with valleys, where are still, or have been, small streams.

Down to the northern shore of the Bosphorus, from the west, comes a spur of the Hæmus or Balkan range of mountains, its water-shed to the north and south being at a distance of five or six miles from the Black Sea, and fourteen miles from the city. Nearly all the artificial ponds for the aqueduct water supply of Constantinople are close upon the south side of this range of hills, the highest point of which may be about 770 ft. This region is commonly called the forests of Belgrade, and has acquired a prominence in English literature on account of the letters written from the village of that name by Lady Mary Wortley Montague, while residing there in 1717. A vast quantity of moisture in the form of snow and rain falls in this region during the winter season, which naturally collects in the ravines, in two small streams, that, finally becoming one, empty into the harbor of the city, the Golden Horn.

When, in the year 330, Constantine the Great came to Byzantium, and founded New Rome, which the Greeks preferred to call Constantinople, in addition to the one hill of Byzantium, he enclosed six contiguous hills; and recalling the unsurpassed length and grandeur of the aqueducts of old Rome, and stimulated by an ambition full of reminiscences of its magnificence, he commenced immediately on the same imperial scale with all his expenditures, to provide water for the crowds that were flocking to this queen city. And the lofty aqueduct which was built by him more than fifteen hundred years since, is still the chief channel for water from Belgrade to the capital.

The well water of the city was then and still is bitter; the water of the two seas was salt; and the only river near by was far too small to afford an adequate quantity. The plan then adopted by his engineers, and the constructions then made, have been retained, with expansions by successive kings and sultans, to the present time.

The course adopted was to make dams across the mouths of the upper valleys, arresting the smallest rill in its progress. From the ponds thus formed, the water was conducted in channels of cylindrical tiles to larger reservoirs formed by larger dams. Those of the lower reservoirs were most solid constructions of marble, 80 and 100 ft. in height. The banks were left in their natural state, the trees growing down to the edges of the lakes.

The people give the name of dam or bendt to the lake formed by the dam; the Persian word bendt being perhaps the same in its etymology as our words *band*, *bind* and *bond*. The water from one set of bendts is conducted by the Crooked aqueduct to the aqueduct of Justinian, and the water from another set of dams which are farther to the west, is conducted by the Long aqueduct, also to the aqueduct of Justinian.

The Crooked aqueduct, so called because it makes a turn or elbow in crossing the valley, is nearly 1,000 ft. long, 670 ft. on one length and 300 ft. on the other. It rests upon three tiers of arches, having a breadth at the base of 21 ft., and at the top of 11 ft. It is a rustic work in fine taste, stretching across a valley 600 ft. wide. There is an arched passage-way through the upper tier of twenty-one arches, by which one can cross from one side of the valley to the other. The whole height of this aqueduct is 110 ft.

The Long aqueduct has two tiers of arches, fifty in the upper tier, and forty-eight in the lower one. Its whole length is about 2,229 ft., its height 85 ft., and it is 12 ft. thick at the top. This aqueduct was built by Suleiman the Magnificent in 1550, as a further supply for the city. It is supplied with water from bendts in a different direction from those which supply the Crooked aqueduct, but the waters of both proceed in stone channels by the sides of the hills, winding with their curves till they reach and unite in the aqueduct called equally that of Constantine and of Justinian. All these aqueducts have gilded inscriptions in Turkish, which speak of their being built or restored by Turkish sultans.

The so-called aqueduct of Justinian, believed by historians to have been built by Constantine, is about twelve miles from the city. It is a very high aqueduct through its whole length, being 112 ft. in height. It is 840 ft. long, and 15 ft. thick at the top. It has four large arches of 50 ft. span each at the bottom, four similar arches in the second tier, and between each arch and at the ends, three tiers of smaller

arches. A gallery pierces the square columns of the first story, giving a passage through its whole length for promenaders. After leaving Justinian's aqueduct, the water follows the right bank of the river Cydaris on the table-land, now crossing a ravine on a single arch, and anon piercing through a hill for a hundred or more feet by a tunnel, till it reaches the elevated plain just outside of the city gates at Daoud Pasha, where it is discharged into a receiving reservoir and thence by pipes of diverse construction, stone, tile or lead, to various parts of the city.

In the early days of Constantinople, an aqueduct, which still remains to constitute a conspicuous object as you gaze from Galata upon the centre of the city, was built by the Emperor Valens, which was intended to convey the water of Justinian's aqueduct from the fourth to the third hill of the city. In the year 370, the Emperor Valens, wishing to revenge himself on the city of Chalcedon, just opposite to Constantinople, razed its walls, and took the stones to build this aqueduct. For some unrecorded reason, it has long ceased to be used for the purpose for which it was erected. It rises prominent in the city, dark, hoar and massive, overgrown with blackbery vines, ivy, and overhanging bushes, which are ever kept fresh by the water oozing from the stones. A path may be followed on its top extending for the length of a mile. Here you find that pipes are laid, by means of which water crosses its path, the aqueduct being used instead of columns, at various distances, for the support of pipes, which constitute a kind of inverted siphon. Of these siphons I will speak more particularly in connection with the next and only remaining aqueduct.

This last aqueduct is of purely Turkisk origin, and was built, in the name of the mother of Mustap a III., the *Validè Sultan*, a little more than one hundred years since. It conveys water from the eastern end of the range of hills of Belgrade, to Pera, Galata, and the villages on the Bosphorus. It commences, as do the others, with dams or bendts to form lakes in the valleys. The lower dam of this one is of marble, 400 ft. long, 60 ft. wide at the bottom, and 130 ft. high. The promenade on this structure is protected by a stone balustrade 4 ft. high; the marvellous effect of its size is heightened by buildings two stories high at each end for the use of royal parties. The water soon after leaving the bendt crosses a valley by an aqueduct supported on two tiers of arches, 80 ft. high and 400 ft. long. A public road passes under it. Its top is covered with marble slabs; the channel is 15 in. wide and 18 in. deep; the velocity of the water, 6 ft. in a second. It has been calculated to be able to supply 6,000,000 of gallons in twenty-four hours.

In the winding course of the canal towards the south, there are several breaks or alterations of level, said to have been devised for the sake of exposing the water in its fall to contact with the air. Branches go off from it to villages on the Bosphorus; and as it approaches Pera on the hill, its water branches off to go four or five villages of which it is the centre, from a receiving reservoir 200 ft. square.

No one of the engineers of these aqueducts availed himself of the fact that water would safely run in pipes and channels having curves of rise and fall. They had not a knowledge of the strength of cast iron pipes, and could only use lead, or tiles joined with cement, which might yield to the pressure of the column of water; and this may have been the sufficient reason for their choosing to depend on a uniform descending flow of the water. There was an experiment, however, which they tried in bringing the water of this aqueduct to the city, which has been uniformly noticed by travellers, and the reason for which it is difficult to understand, nor have I ever known it to be satisfactorily explained. When the water canal reached the edge of a valley which it must necessarily cross, it was allowed to descend the hill to the foot of a stone column 30 to 70 ft. high according to circumstances; then a pipe of lead conveyed it to the top of the column into a small open basin; from this basin it overflowed into a second pipe likewise open at the top, and descending passed under ground some hundred feet to a second column of the same height, where the same process was repeated; and so on till the top of the opposite hill or rise of ground was reached.

As we knew that the water could in no case rise higher than the level of the last column from which the water had flowed, the question arises, what advantage did the engineers expect to gain by the contrivance? Did they believe that their pipes

would not burst in the circumstances in which they had disposed them, but would burst if carried continuously down and across the valley? Or did they think that they could raise the water higher than they otherwise could at the delivery end of the aqueduct?

The name they themselves gave to these columns was *sou-terazou*, or water balance, which may be a clue to their theory. Andréossi observes respecting them: "It requires but little attention to perceive that this system of conducting tubes is nothing but a series of siphons open at their upper part and communicating with each other. The expense of a conduit by water balances is estimated at only one-fifth of an aqueduct with arcades." George Buchanan, Civil Engineer, thinks that Andréossi has misconceived the nature of this device.

These are all the artificial means of bringing water to the city from without, except what is reported to be brought from certain springs five or six miles to the west, from Kavasskieui and Chalcali. But from the little that has ever been said regarding them, I am confident that the number of persons supplied from thence must be very few.

At the present time the Government is engaged upon a new scheme for an additional supply, the deficiency being felt in proportion as the population increases. The stream which empties into the harbor is to be dammed up, and from the surface of the pond created, the water is to be raised by steam power, 100 ft., and conducted to the city by pipes.

We now leave the aqueducts and come to the distribution of the water in the cities and villages. It is distributed into covered cisterns, to the public fountains, and to the mosques and khans; but not to private houses, with few exceptions.

Of cisterns and basins, in the time of the Greek Empire, there were nineteen large ones established in the elevated parts of the city. But owing to the carelessness of the Turks, and possibly to different notions of the best method of disposing of the water, they may be said to be all of them either in ruins or not used for the purpose for which they were created. The location of them all is now known, and can be pointed out. Some of them have been unroofed (if they were ever covered), and converted into vegetable gardens, or filled with houses; in one is a mosque. Into others one can grope, as into the subterranean regions of a palace in ruins. The most famous of thess cisterns is the *Bin bir direk*, or Thousand and One Columns, which is still complete in its outline. You descend from the street, to the bottom of it, about 50 ft., and find a few score of people, squalid and unhealthy, availing themselves of the humidity of the atmosphere, to pursue their profession of twisting silk. Its vaulted roof is supported by 224 marble columns, symmetrically arranged, about 20 ft. apart, and 70 ft. high; one-third of their height being buried in accumulations of earth. Grated openings have been made in angles at the top to furnish a dim light. At three points near the top may be seen channels worn where the water formerly ran in. It has been estimated to cover an area of 20,000 sq. ft., and that it would have contained 1,238,000 cubic ft. of water, and would alone have sufficed for the consumption of the city for fifteen days. The pillars bear occasionally an inscription in Greek, *Euge Philoxene*: Hail! stranger's friend!

Another cistern, the knowledge of which has been gained and lost several times since the Mohammedan conquest, is called the *Yeré Batan Serai*, or the sunken or engulfed palace, such is its vastness and the mystery with which the perhaps fabulous reports of its extent cause it to be regarded. It is in the neighborhood of the Mosque of St. Sophia, and was built by Constantine. It has also a vaulted roof, and is supported, as far as examined, by 336 granite columns, each of a single block, with Corinthian capitals, and 15 ft. apart; the length of it is marked by rows of sixteen columns, and its width by rows of twenty-eight, being about 275 ft. wide by 475 ft. long. The cistern usually appears to the traveller, with the columns hidden to two-thirds of their height in water, but that portion of them which is visible is covered with sculptured ornamentation. The spot from which you gaze over its waters is not a regularly constructed opening, nor is it known where there is one; this has been made by the failure of some of the pillars to sustain the superincumbent mass. The roof has failed in several other directions, not visible from the place where you look in. It is not known who or how many have the means of obtaining water from this cistern. Boats have at times been in use for the curious traveller, and an Englishman is said on one occasion to have followed a canal from the

cistern in a boat for two hours in a right line, and returned without reaching a termination.

One quite perfect but empty cistern is the Budrum. It is not as large as some of the others, but is very beautiful in its architecture. Its columns are three times the circumference of those in other cisterns, each of a single block. It is also occupied by silk spinners, like that of the Thousand and One Columns.

The original solidity, the number, the capacity for holding water, and even the architectural beauty of these cisterns, render them a most remarkable branch of the earliest Constantinople water system. They were designed as cisterns of reserve, either to enable the city to stand a protracted siege, or to respond to the necessities of the population, when in consequence of drought or accident the water in the reservoirs outside should be exhausted. But the conquerors of the infidels never believed in a coming time when they should be besieged, and their undertakings in architecture were almost entirely religious or commercial. Although they have suffered these cisterns to be disused or ruined, they might some of them be converted to their original purpose. The ground on which the houses stand has been gradually raised by the debris of four centuries, and in digging for the foundations of modern edifices, accidents occasionally reveal crushed cisterns of greater or less extent.

The large use of the public water for public fountains appears to be the Turkish substitute for the public cistern. The word fountain as employed in Turkey never suggests the mere use of water in an ornamental *jet d'eau*. It refers to the place where the water carrier or the people may go, and by means of a faucet draw water for themselves, immediately closing the faucet. The structure over and around the pipes may be the most costly, of the richest stones and covered with gilding, so that one is astonished at its elaborateness and magnificence, yet no water is freely flowing, except when some one is waiting with a vessel to be filled. The fountain is but a public pump.

Some of the fountains, especially in the Christian quarters, are as plain as it is possible for stonework to be made. In the Mohammedan quarters they are very numerous, because there is no pious work in which a rich man so readily engages as the construction of a fountain, which bears his name inscribed in poetical lines, for the benefit of the people of his quarter, although the water is drawn from the public aqueducts.

The water carriers are under the control of the water superintendent, and receive a fixed and moderate price for each skin of water which they empty at your house. Twenty years since it was not more than a penny, or a penny and a half according to the distance, for the ten gallons of water the skin would hold; the water itself is public and free without tax of any kind. In my own house this water used to be emptied into a large mouthed earthen jar, as large as those in which the Forty Thieves hid themselves. They are sometimes made as large as a hogshead.

The water is frequently discolored after rains with the light loam of the fields; but I never knew it to have a disagreable odor or taste derived from microscopic plants.

The whole direction of the bendts or lake reservoirs, aqueducts and fountains, is under an officer of high rank, who has three to four hundred Turks and Christians constantly employed under him. The pipes, as large as 3 in. in diameter, are of lead, cemented at the joints with hemp and a glutinous mixture. Some have attempted to calculate the cost of the various public water works and have estimated it as high as $50,000,000.

Thus much as regards the public provision of water. But the record of their experience has long sing taught people of all classes, and especially the more provident Christian races, not to rely on the aqueducts alone.

In all the mosques, churches, khans, and in most of the private houses, there are both wells and cisterns. The water of the wells is obtained without digging to great depths, 12 to 30 ft., but it is invariably disagreeably bitter. It is thoughtfully used for gardens, for cleaning the house and laundry purposes; but never for drinking or cooking.

In constructing a cistern, it is built of stone or brick, well cemented, and of the greatest possible size that the ground of the edifice or house will allow. The cisterns receive all the water they can possibly collect from rain during six months of the year, and the master of the house carefully keeps the key, that the water may not be wasted before the dry season arrives. The

surface of the roofs is large in proportion to the number of houses, because the houses are usually not more than two stories high. The water of the first rains of autumn is carefully turned off from the cistern for the sake of maintaining its purity. In consequence of this, and the absence of coal smoke, the water is remarkably pure.

When the American Robert College was building last year at Constantinople, under Dr. Hamlin's supervision, his first care was to have a large cistern dug in its central court, the building being more than 100 ft. square. He both saves the water of the roofs, and obtains the privilege in winter of filling it from the aqueducts. It is large enough and receives water enough for a three months supply and with some to spare, for a family of two hundred and fifty persons, through the period when there might not have been a drop of rain. A well in addition has been dug upon the premises, from which water may always be obtained by means of a horse pump.

In the vegetable gardens, water is drawn from wells which are from 50 to 75 ft. deep, and 20 ft. diameter at the bottom, by means of large water wheels with buckets, which are turned by a horse, and occasionally one may see the old fashioned well-sweep.

In addition to the supply for houses from the aqueducts, there is an arrangement for most of the larger houses in the villages on the banks of the Bosphorus, which has not been noticed by any travellers. The shores of the Bosphorus rise more or less precipitously to the height of a hundred feet or more, and then the land stretches out in a plain. The owners of houses owning lands up the hills tunnel the rocky ledges a distance of from 50 to 150 ft., and construct receiving reservoirs in the rock on the sides of the hills, and, conducting the water by means of cylindrical tiles down the hill from one reservoir to another, they obtain usually from the percolation of the water through the slaty sandstone, or the flow from the hollows in the plains above, an abundant supply for the year, available on every story of their houses.

There is a fountain on the Asiatic side of the Bosphorus at Beikos, which is day and night pouring out 4 in. streams of water, from several brass pipes. This water filled into barrels is floated down the current in barges for the wants of all the shipping and the Imperial fleet. In fact, if Constantinople were only attacked by land, the supply of water from this and other magnificent and inexhaustible springs on the eastern side of the Bosphorus would be abundant for its wants.

The facts already mentioned give a general view of the nature of the arrangements of the water supply for Constantinople. There are still some additional observations worthy to be made, if they have not already suggested themselves to your minds.

1. The catchment basins receive water from only a very limited surface. As it can be traced upon the map, it extends to a very small number of square miles.

2. The sides of the hills are all covered with forests of oak and chestnut, and also far beyond the spots whence any water could flow to the reservoirs. This devoting so large a space to forest wildness within ten miles of a million of inhabitants is no mystery to the people. It is the result of a custom, and a stringent law enforced for 1,500 years, and not a new discovery. The edicts of the Greek emperors were very early issued requiring the planting of trees and forbidding any person other than the authorities to cut down a single tree, and the Turks enforce the same law. There may be, there are differences of opinion as to the physical laws by which the perpetuation of forests secures rain and preserves moisture, but there is no difference as to the fact that with the devastation of the forest on the hill-side, the usual and regular flow of water is greatly diminished. The subject is discussed in more than 200 pages in Marsh's "Man and Nature," in which is a compilation from many authors on the influence of denudation on the land as regards moisture, and of the conflicting influences which operate. No record exists of the destruction of these forests on any occasion except once in 1823, when the Janissaries were destroyed by Sultan Mahmoud. It was a question of life or death, and to drive the remnant of them out of these forests, they were set on fire; and miles of trees, hundreds of years old, were consumed, and the fleeing Janissaries were shot.

Other edicts prohibited under severe penalties the diverting of any portion of the water by any individual, and, as is extravagantly reported, requiring a pound of gold for each ounce of water stolen.

3. The quantity of water furnished by

these aqueducts is very small when compared with that furnished for the modern cities of Europe and America. Andréossi, formerly French ambassador in 1814, the most exact of all who have written upon the subject, estimated that the quantity supplied for each man, woman and child, from all the aqueducts, was 400,000 cubic ft. a day, which is equal to 3,200,000 gallons; and, on the supposition that the city proper contains 600,000 inhabitants, is only two-thirds of a foot or five gallons a day to each person. We know that in many of our cities the draft from the aqueducts ranges from 40 to 90 gallons for each person. Dr. De Kay's calculation, one of less exactness, was that 15,000,000 gallons were supplied each day.

4. Water is only provided for domestic purposes and drinking, and religious ablutions. It is not provided for steam engines or breweries. There are no hydrants. The fire engines, carried on the shoulders of four men, squirt the water poured into them only from the skins of water carriers, in case of a fire. They will hold about a barrel. The water of the Albany aqueduct is used by 144 steam engines, 36 breweries and malt-houses, 313 street hose, and for other similar purposes.

5. The Constantinopolitans by no means make as lavish a use of water as is frequently represented by travellers. Of course the amount that would be brought to any family by a water carrier and paid for, must be very small when compared with the quantity used where it runs freely in a house from several and many faucets. And they do not use nearly as much in baths or in religious ablutions as would be supposed. While it is true that in every quarter there are public baths which are greatly used, and private baths of the same kind are not unfrequent, yet it must be remembered that they are only hot vapor baths. The inner room is occasionally highly heated and the air kept moist by the evaporation of water at times thrown upon the hot floor and walls, to make the heat agreable and endurable. One room serves for all the customers. After an abundant perspiration, the person goes to a marble bowl and is washed or washes himself in warm water. But the quantity of water employed by any person taking a cold or warm bath by immersion is probably three or four times as great as would be used by a customer in a public bath in Turkey. Besides, the baths are not used by the public generally during more than eight hours in a day.

In the case of ablutions before prayer five times a day it is purely ceremonial, and very little water serves the purpose. In the courts of the Grand mosques fifty faucets in a row give out when opened a tiny thread of water, and the intending worshipper, crouching before it, touches his ears, arms and ankles with the fluid, not perhaps consuming more than half a pint.

6. A famine of water is not unfrequently experienced in Constantinople; a want of water is constantly feared. This is in great measure owing to the neglect and disuse of the public cisterns which were expressly designed to receive the overplus of the water from the winter rains. In the summer and autumn months it is not unusual that three, four, or five months pass without any fall of rain that can be collected. At such times, of course, water is sold at high prices by those who have cisterns or who bring it from the perennial springs of the Asiatic Bosphorus.

When water runs low in the reservoirs, nine out of ten of the public fountains will be closed by the water superintendent; those left open will be surrounded by the public water carriers, who almost monopolize the one faucet from which the small stream can be drawn, while a crowd of men and women press clamorously for a turn to draw it into their own private vessels.

At such times of drought, notwithstanding the interpretations usually given to the doctrines of the Mohammedans, as if they were absolute fatalists, an interpretation we have given on account chiefly of their former fatuity in the matter of submission to the plague, yet when a drought becomes serious the monarchs have issued proclamations calling upon the faithful to assemble and pray for rain. And they have been assembled in consequence by tens of thousands on the open plains around the city, including all the children of the public schools, and there invoked the God of Heaven to send rain.

On the summit of the Giant's mountain on the east shore of the Bosphorus there is a convent of dervishes, where in such times of drought a dervish watches the approaching answer to prayer, looking across the waters of the Black Sea to the north, to see the first rising of the cloud big with rain.

And his report is quickly heralded to the anxious citizens.

In illustration of the remarks with which I commenced, I must again allude to the admiration and love of the people for pure, sweet water. If it is not the sole beverage, still, its place is not supplanted by mingling it with spirituous liquors, nor by using tea or coffee as a substitute for it. Tea is drunk by not one in a thousand, and coffee, from cups holding much less than a gill, and spirituous liquors, by the few that use them, are swallowed without adding any water.

All the fountains are supplied with cups; at the mosques, water may frequently be found ready poured out in long rows of cups for each passer-by to take what he needs, without pay; this provision being made in consequence of the pious legacy of some individual.

In the business streets, there are shops devoted principally to the sale of water, by the keg, or by the glass, at one-tenth of a penny for a glass, the water being brought in such cases from well-known and favorite springs, from ten or fifteen miles distant.

I once spent a few days at Alem Dagh, or "mountain of the world," a village twelve miles from the city, near the hill of that name. From the foot of the hill, in different ravines, burst out small springs of water, each of great purity, but with a slighly differing taste. The citizens passing the summer there, in the morning or evening, give their orders regarding the water to be brought to them. And thus one would say, bring me water from Silver spring, another, bring me from Apple spring, and another, from Diamond spring, and so on. And when the waters were brought, each one could distinguish the taste of his favorite water, from that of each of the other springs.

Pic-nics and summer excursions are all devised primarily to visit a fountain or spring in the country, rather than to visit a grove or a hill.

I will close with only one or two remarks suggested by our circumstances in Albany. Having in mind the various schemes for a fuller supply of water proposed by the worthy Water Commissioners, the question presents itself, whether something might not be accomplished by maintaining the water shed of our reservoirs carefully covered with a forest, and thus protect the soil from the influence of the sun and winds, and insure the regularity and permanence of the flow. These forests at the same time might aid in protecting the vicinity of the city from the spread of the dunes or sands. And, lastly, the restriction of the use of public water to the amount specifically paid for, being only a question of time, all are interested to provide for the different uses of city life, such an amount of water as can be obtained from wells and cisterns on their own premises. Others also might be maintained at the public expense.

LOCOMOTIVE POWER ON RAILWAYS.

By C. DRAPER, C. E.

From the "Engish Mechanic and World of Science."

The volocity of any machine is uniform, accelerated, or retarded, according as the work applied to it is equal to, greater, or less than the work done in overcoming resistances. For example, suppose a locomotive to draw from rest a train of carriages on a level line. Now, if the fuel supplied to the furnace be in constant quantity, the work applied will at first exceed the resistance, and as the resistance increases with the velocity, it will soon become equal to the work applied, and the velocity will then be uniform. If now the steam be shut off, the resistance will gradually decrease the velocity, until the train is brought to rest.

The total resistance overcome by a locomotive is in this case made up of:—

1st. The friction of the train, including the tender, made up of rolling and axle friction.

2d. The friction of the machinery of the engine, including its wheels and all moving parts.

3d. The resistance of the air against the train.

4th. The back pressure on the piston necessary to force the waste steam up the funnel, causing the blast.

5th. If the train ascend the gradient, the locomotive will have to overcome an additional resistance equal to the component of the total weight down the incline, but if it descends, the motive power will be increased by the same quantity.

As an example, let us find the total resistance in pounds per square inch on the pistons due to the motion of a train weighing 80 tons, including the engine weighing 25 tons, travelling at the rate of 40 miles an hour.

By experiment, it has been found that the force of traction or resistance from friction of the train and engine, considered as a carriage, is about 7 lbs. per ton, when the wheels and rails are in good condition; therefore $7 + 80 = 560$ lbs. is the resistance of the train and engine due to the rolling and axle friction.

To reduce this resistance, which is overcome at a speed equal to the velocity of the train to pounds on the surface of the pistons, we must ascertain the ratio of the velocity of the train to that of the pistons, for which we require the diameter of the driving-wheel and the length of the stroke. Let these be respectively 7 ft. and 21 in.; then while the driving-wheel moves through

$$\frac{7 \times 22}{7} = 22 \text{ ft.},$$

the piston moves through

$$\frac{2 \times 21}{12} = 3.5 \text{ ft.}$$

Therefore by the principle of constancy of work

$$\frac{560 \times 22}{3.5} = 3520 \text{ lbs.}$$

is the resistance due to the friction of the train overcome at piston speed.

The friction of the machinery of the engine is made up of two parts—one fixed, namely, that of the unloaded engine, and generally taken at 1 lb. per sq. in. of piston area; the other, which varies as the load, and is generally taken as one-seventh of it.

The resistance due to the passage of the train through the air is proportional to the square of the velocity, and is expressed by

$$\frac{.12\, M^2\, l^2}{D^2},$$

where M is the velocity of the train in miles per hour, l the length of the stroke, and D the diameter of the driving-wheel in inches; substituting for these letters their values, we shall have

$$\frac{.12 \times 40 \times 40 \times 21 \times 21}{7 \times 7 \times 12 \times 12} = 12,$$

which is the resistance in pounds per square inch of piston area due to the resistance of the air, constituting part of the load. But we have found the resistance due to the weight of the train and engine to be 3,520 lbs. on both pistons; therefore, taking their diameter to be 16 in., the sum of their areas will be 402 sq. in., and this resistance, reduced to pounds per sq. in. of piston area, will be

$$\frac{3520}{402} = 8.8 \text{ lb. about,}$$

constituting the remaining part of the load. The total load, therefore, is $12 + 8.8 = 20.8$ lbs. per sq. in. The friction due to the load is one-seventh of this, or 3 lbs. per sq. in. nearly.

The back pressure on the piston caused by the blast is proportional to the velocity, and is taken as

$$\frac{28}{40} \times \frac{Ml}{D},$$

the letters representing the same quantities as before; therefore, this resistance is

$$\frac{20 \times 40 \times 21}{43 \times 7 \times 12} = 6.5 \text{ lb. nearly.}$$

By adding up these several resistances, namely:

Resistance due to weight of train	= 8.8 lb.	per sq. in.
Resistance due to resistance of air	= 12.0 lb.	" "
Friction of engine due to the load	= 3.0 lb.	" "
Friction of unloaded engine	= 1.0 lb.	" "
Resistance due to blast	= 6.5 lb.	" "
Total resistance	= 31.3 lb.	" "

We find that when this train of 40 tons is travelling at the rate of 40 miles an hour on a level rail, the resistances to be overcome amount to 31.3 lbs. per sq. in. of each piston; so that to maintain this velocity the average pressure of steam throughout the stroke must be 46 lbs. above a vacuum.

This 31.3 lbs. per sq. in. of the pistons is equivalent to a force of

$$\frac{2 \times 31.3 \times 201 \times 3.5}{22 \times 80} = 25 \text{ lb. per ton,}$$

acting at the rail or at the speed of the circumference of the driving-wheel.

According to experiments by Mr. Gooch upon a train of 100 tons, the average resistance of engine and train at a speed of 44.1 miles an hour was 25.5 lbs. per ton, which agrees very closely with the result of the above calculations.

Besides the above resistances, there are others which cannot be estimated separately—such as that caused by the vibration of the ground, and the great resistance of side and directly opposing winds.

The force communicated to the driving wheels is that necessary to overcome the load due to the weight of the train and the resistance of the air; the former, we have seen, is 3,520 lbs., and the latter is $12 \times 402 = 4{,}824$ lbs., both acting at piston speed; the sum of these, reduced to the velocity of the driving-wheels, is equal to

$$\frac{8344 \times 3.5}{22} = 1{,}327 \text{ lb.}$$

Now, it is manifest that the friction between the driving-wheels and rails must at least be equal to this force; otherwise the driving-wheels could not have sufficient "bite" upon the rails, and would revolve without moving the train.

The co-efficient of friction, which we may take to be that of wrought iron upon wrought iron, will vary much with the state of the weather, and also with the condition of the tires and rails; thus, when the rails are very dry, the friction may amount to a fourth of the weight upon the driving-wheels; but when they are frosty or "greasy," it may fall as low as one-eleventh. In an express engine, weighing 25 tons, the weight upon the driving-wheels will be about 10 tons, therefore in the worst condition of the rails the friction will be about 10-11ths of a ton, or 2,036 lbs., so that in this case we have 2,036—1,327 = 709 lbs. to spare.

From what has been said, the apparently paradoxical statement is true, viz., that although friction is one of the chief resistances to be overcome on railways, still it is the necessary condition of movement at all. In the event of the driving-wheels slipping, which we frequently see in damp weather, the rails should be sprinkled with dry sand to increase the friction. For this purpose the locomotive is provided with sand boxes, from which pipes are led to the front of the driving-wheels just above the rails. When it is necessary to sand the rails, a valve in the box is opened by means of a handle within reach of the driver.

In the case of goods engines the "bite" of the wheels is required to be much greater than in the case of passenger engines. In the former two or more pairs of wheels are coupled together, and the weight which rests on the coupled wheels is available to produce friction; sometimes, indeed, when the gradients are very steep, the weight of the tender is also made available by coupling its wheels to those of the engine. Thus in the case of a goods engine weighing 30 tons, of which 10 tons rest on the driving and 10 tons on the trailing wheels, we have 20 tons available for friction when these two pairs of wheels are coupled together.

Erosion in "Woolwich" Ordnance.—The committee secretly appointed to inquire into the destructive action of the products of combustion on the upper grooves and lands of "Woolwich" rifled ordnance, proposes once more to stop the windage by the use of a thick wad. The "Woolwich" "system has the disadvantage of local scoring," says Colonel Campbell, the gunmaker; and the committee, instead of proposing to alter "the system," suggest the oft-tried remedy—the wad. The Navy has strenuously objected to every wad heretofore supplied—first, if it breaks up, as dangerous to the loaders of weather guns, in consequence of the burning fragments being blown back upon the following powder charge; and, secondly, if the wad does not break up very small, as highly dangerous to friendly ships, and, in turret vessels, destructive to the decks of the vessels firing. If the inshore line of the fleet recently gathered at Spithead were to have fired at targets, through the interstices between the ships in the outer line, the wads, if used, would have endangered the lives of men in the outer line. Yet, in naval warfare, it is the common practice to fire over or close past friendly ships, with full confidence in the safety of the practice. It is understood that the committee of soldiers, who, as usual, decide these naval artillery questions, suggest that wads should only be employed in peace, when guns are very seldom fired, but that in war, when rapidity of fire may be expected, the wads should be omitted.

PROGRESS OF THE IRON AND STEEL INDUSTRIES.

By DAVID FORBES, F. R. S., etc.

Condensed from "Journal of Iron and Steel Institute."

Africa.—The rich hematite iron ores which were in ancient times extensively worked by the Romans, and abound all along the seaboard of Africa as far as the Tunisian frontier, have not hitherto attracted as much attention as might have been expected from their local position and excellent quality, which makes them so suitable for the production of Bessemer pig. The mine of Alisi Mokra, on the banks of Lake Tetzara, purchased by M. Talabot, has been connected with the port of Bona by a railway some twenty miles in length; owing, however, to the exhalations of the lake, the district becomes so unhealthy in the summer season, that all work has to be suspended.

The great obstacle to the development of these mines is the want of fuel with which the ore can be smelted on the spot, as, although there is abundance of wood, it is chiefly cork oak, which is too valuable to be employed for making charcoal; all the ore has therefore been as yet exported chiefly to France, for which object a powerful line of steamers was established to run to Marseilles. It is now, however, proposed to erect blast furnaces, and smelt the ores, or a certain amount of them, on the spot, with coal which the steamers can bring as return cargo. A company called the "Franco-Algerienne," has recently been formed for working iron mines at Soumah, near Bonfarik, in Algeria, from which place, hitherto, the exportation of ores to France, Belgium, Germany, and England, has been at the rate of about 100,000 tons per annum; the mineral is of excellent quality, quite free from sulphur and phosphorus.

Australia.—A limited company, entitled "The Fitzroy Bessemer Steel, Hematite Iron, and Coal Company," has recently been incorporated in London, for the purchase of the Fitzroy estate (about 1,702 acres freehold land), ironworks, and coalmines, in New South Wales, on the main line of railway from Sydney to Port Jackson. The ore is stated to be rich hematite, perfectly free from phosphorus, and of a peculiar porous character, which must facilitate its reduction. The coal is said to produce a hard coke equal to the best Scotch, and limestone is at hand in abundance, as well as fire-clays, from which bricks, equal to the best Stourbridge, are made.

Austria.—The blast furnace of Kalán, in Siebenbergen, is now being worked with a mixture of ¾ths coke, from lignite, along with ¼th charcoal.

From a paper on the mining industry in Tyrol, published in the Viennese "Techniker," we extract the following data:—The iron ores smelted in the Tyrol are all spathic carbonates of iron, occurring either embedded in the clay-slates of Gelraberg, at Pillarsee, or in lodes accompanied with carbonates of lime, magnesia, and barytes, in the micaceous clay-slates, as at Schwaz, and other places; the poorer ores of Gelraberg—containing about 2.22 per cent. protoxide of manganese, 0.006 per cent. phosphoric acid, 0.028 per cent. sulphur, and 0.014 per cent. copper—are smelted at the Pillarsee Works, whilst the less pure ores, from Schwaz, with about from 32.5 to 36.5 per cent. iron, go to the Jenbach Works. The roasting takes place in kilns, using as combustible the small from the charcoal, employing in 24 hours 2½ cubic ft. to calcine 3 tons of ore; but recently roasting kilns on the top of the furnace were supplied, and the waste gases have been employed at Jenbach, and calcine 3 to 3½ tons iron ore in the 24 hours. At Jenbach, the ore after calcination is tipped as hot as possible into tanks, 72 ft long, 14 ft. broad, and 1¾ ft. wide, where it is washed with a continuous stream of water, in order to remove as much sulphur as possible from it (in the state of soluble sulphates) before being smelted.

Belgium.—The last accounts bring us the figures showing the importation and exportation of iron during the first two months of the present year; the importation has increased from 20,000 tons during the first two months of 1872, to 35,000 in those of 1873, a result entirely due to England, from which country the imports of iron have increased from 15,000 to 30,000 tons, the additional 15,000 tons being composed of 8,000 tons of pig iron and scrap, and 7,000 tons of rails. The exportations have slightly increased, being 35,700 tons against 33,500 tons in the cor-

responding period of last year; the details being an increase of 1,000 tons sent to the Zollverein, 1,000 tons to England, 1,000 tons to Brazil, 3,000 tons to Spain, 5,000 tons to Italy, whilst on the other hand there was a diminution of 2,000 tons to Holland, 8,000 tons to Austria, and 200 tons to the United States of America. Even this small increase is supposed to result from old contracts, which have not been renewed.

The last news from Belgium show a want of confidence in the state of the iron trade, due to scarcity of orders, few of the old ones being renewed, and the letting out of many puddling furnaces; it appears to be the general impression that a reaction is now about to set in, and that the excessively high prices which have ruled of late, have at last checked the consumption of iron. The shareholders of the Société Thy le Chateau held their meeting on the 8th March, when it was announced that the second blast furnace at Wey St. Martin, and the group of 80 coke ovens, were being rapidly proceeded with. The production of the blast furnaces had been 48,151 tons of pig iron (including 527 tons castings), and the rolling mill had turned out 32,851 tons of rails.

On the 24th April, the first rotary puddling furnace on Danks' system in Belgium was put in operation at the Sclessin Iron Works, with complete success, the iron produced being at the same time pronounced to be decidedly superior to that made from the same pig iron by hand puddling. A three-high rolling train on Louth's differential system was also put in work in the last week in April at the L'Esperance Iron Works, at Liège, with such satisfactory results that the company are understood to have already ordered three more trains on the same system.

Canada.—From this country we hear of several new undertakings about to be started on a considerable scale, especially in Nova Scotia, where the construction of the Inter-Colonial Railway promises, by bringing the iron ores into connection with the coalfields, to inaugurate a new era in the metallurgical industry of the Dominion. Amongst others, a company to be called the British North American Iron and Steel Company, with a capital of £400,000, is about to be brought out for purchasing the Londonderry and Acadian mines, situated in the County of Cumberland, in Nova Scotia, and for establishing the manufacture of steel rails, wheels, tyres, axles, and other railway materials, more especially under Mr. Siemens' patents. The ores in question are the native oxides, specular and magnetic, as well as red, brown, and yellow hematites, along with ankerite, a carbonate of lime and iron, particularly valuable as a flux to the other iron ores. The quantity of these ores appears to be very great, the present Director of the Geological Survey of Canada, Mr. Selwyn, estimating that down to the depth of 250 ft. alone, there must be more than 5¼ millions of tons of available iron ore. In quality, numerous analyses show them to contain only a minimum quantity of sulphur and phosphorus, along with from 40 to 56 per cent. of metallic iron; and as coal of excellent quality can be obtained from the Springhill collieries at an estimated price of not more than 6s. 6d. per ton, or coke at 12s. 9d. per ton delivered at the works, it is calculated that the ton of Bessemer pig will not exceed a cost price of £3 10s. on the works. It is proposed to erect one coke blast furnace of sufficient capacity to produce from 300 to 350 tons of pig iron per week, and such a number of steel smelting furnaces as will insure the production of about 40,000 tons of steel ingots or 30,000 tons finished steel per annum, which is estimated to cost about £8 per ton on the works.

Another enterprise in the same direction, and of very similar character, is the proposed Pictou Iron Company, to be formed with a capital of £250,000, for acquiring and developing deposits of iron ores in Pictou County, Nova Scotia, held partly in fee simple and partly under mining grants from the Government of Nova Scotia. The ores consist of spathic carbonates of iron, containing 42 per cent. of iron, red hematites with 50 per cent. of iron, specular oxide of iron containing 60 to 68 per cent., and brown hematites with from 62 to 65 per cent. of metallic iron. The ores have been reported upon by Mr. Dawson, and are stated to be practically inexhaustible, more than two millions of tons having been already proved, which can be extracted by open-cast workings, so that it is estimated that the ore delivered at the furnaces will not exced 4s. per ton.

France.—The "Bulletin du Comité des Forges d'Avril, 1873," describes the French ironworks as being actively engaged in completing back orders, which will insure

them full work for a great part of this year; at the same time there is becoming general a rather anxious feeling for the future, since it is quite evident that the extremely high prices of iron are telling more and more against its increased consumption, especially in the building trades, where wood is once more taking the place of iron, and it is consequently expected that a diminution in the demand will ensue, which cannot but end in a general lowering of prices. This feeling appears to have increased according to the very latest accounts, and the situation of the iron trade is generally regarded as not nearly so good as it was some months back; it is rumored that some of the ironmasters in the neighborhood of Maubeuge are about to put out some of their fires and diminish the number of their workmen.

During the first three months of this year, the Customs House returns of the metallurgical importations and exportations are as follows:—

142,000 tons iron ores were imported, being an increase of 36,000 tons over that of the same period in 1872; amongst these it is remarked that the importation of iron ore from Belgium has decreased, whilst that from Spain and Algeria has more than doubled.

The exportation of pig iron has increased by 3,300 tons, whilst that of ores has diminished by 13,000 tons, as is also the case with wrought iron. The exportation of rails is only 8,000 tons against 12,000 tons exported during the first three months of 1872; whilst the exportation of steel in bars has diminished to one-half, being only 2,500 tons, instead of 5,000 tons during the first quarter of last year. In all, the decrease amounts to 9,000 tons, and even if we give full consideration to the fact that 1872 was an exceptionally favorable year, yet it is still evident that there is a serious falling off.

According to the "Bulletin du Comité des Forges de France," the total quantity of cast iron made in France during the year 1872, amounted to 1,181,262 tons, of which 1,002,601 tons were smelted by coke in 113 blast furnaces, which gives a mean production per blast furnace of 8,878 tons per annum, or 34 tons per day of 24 hours. In the year 1865, the mean was only 19 tons per day, obtained from 121 blast furnaces, which yielded a total quantity of 224,453 tons in that year. During 1872, the total quantity of charcoal iron produced in France was 178,571 tons obtained from 115 blast furnaces, which consequently is an average of 1,533 tons iron per blast furnace, or about 4 tons per day of 24 hours. In 1865, 208 charcoal blast furnaces were in operation, and produced in all 377,376 tons charcoal pig iron, being at the rate of 1,814 tons per annum, or nearly 5 tons per day.

The quantity of iron and steel rails supplied by the French ironworks to the various French railway companies, during the year 1872, is given at 104,000 tons iron, and 52,000 tons (or nearly 1-3d) steel rails, in addition to which 11,000 tons only were imported, so that the total consumption of rails in 1872 in France amounted to 167,000 tons; as the production during the same year was 209,841 tons, it follows that about 42,000 tons were exported from France to other countries. The total consumption of iron in 1872 is given at 874,000 tons.

As showing the increase in the value of the metallurgic exportation from the ironworks in the basin of the Loire to the United States, it may be mentioned that in 1870 the value was returned at 266,000 francs; in 1871 at 712,000 francs; but in 1872, at no less than 3,326,000 francs, or considerably more than ten times what it was only three years before.

GERMANY.—According to the "Zeitschr. f. d. Deutsch-Oesterr. Eisen. Stahl u. Maschin. Ind.," 1873, No. 2, the employment of iron ores imported from foreign countries is becoming more and more general on the Rhine, especially in Westphalia, for the production of Bessemer pig; for this purpose, at the Phœnix Iron Works, the following ores are smelted:—Magnetic oxides of iron, from Mokta-el-Hadid, in Algeria, containing no sulphur, but with from 0.013 to 0.031 per cent. phosphorus and from 0.024 to 0.070 per cent. copper; specular oxide of iron from Elba containing 0.008 per cent. phosphorus, along with 0.17 per cent. sulphur; hydrous red and brown hematites, from Bilbao, containing 0.28 per cent. sulphur, 0.06 phosphorus, 0.98 bismuth, 0.12 tin, and 0.02 copper; Servian magnetic oxides of iron, with 0.025 per cent. phosphorus, and 0.072 copper; and Swedish magnetic ores, containing from a trace to 0.04 per cent. sulphur and 0.02 to 0.04 phosphorus.

The official statistics of the mining and metallurgical industries of Prus ia have

been published, for the year 1871, by the Ministry of Commerce, Industry, and Public Works in Berlin.

We find from the tables, that the total make of cast iron of all kinds amounted collectively to 28,926,868 zollcentners, or 1,446,343 metrical tons, against 23,111,-823 zollcentners, or 1,155,591 tons, in the preceding year, showing an increase over it of some 290,753 tons.

The total production of wrought iron of all descriptions being 833,473 tons in 1871, as compared with 756,092 tons in 1870, these figures show an increase of 77,381 tons, or more than 10 per cent. augmentation on the make of the previous year.

The steel industry of the Prussian Provinces has not been less active during the year 1871, and has also shown a large increase over the previous, and in fact over any former year's production. The official returns for 1871 show that during this year 16,552 workmen were employed by the different steel works.

Looking back on the three previous years' returns, it will be at once seen how steadily the manufacture of steel has gone on augmenting each year in importance, as well as, it may be added, in the quality of the product. The following statement shows the relative quantities made respectively in each of the four years from 1868 to 1871:—

Year.	Cement and Puddled steel.	Bessemer and cast steel.	Refined or Shear steel.	Total in metrical tons.
1868.....	29,151	88,2 4	4,986	122,351
1869.....	29,[illegible]12	102,772	6,981	149,365
1870.....	32,08[illegible]	120,520	5,294	157,900
1871.....	35,037	148,165	8,948	192.150

HOLLAND.—In the Grand Duchy of Luxemburg the Government has granted 400 hectares (988 acres) of mineral land to a German company, formed by a combination of several German Banks, at an annual rental of 300,000 francs (£12,000), payable for 50 years, and the Luxemburg owners of ironworks have also constituted a syndicate and obtained a similar concession on the same terms. These concessionaires have overtaken the obligation to consume in the Grand Duchy the entire produce of the mines conceded, and it is reported that the German company intend erecting ten blast furnaces at the mines. After having made these grants, it is understood that the Luxemburg Government does not possess more than about 300 hectares of mineral land (741 acres), not already disposed of.

From an exhaustive report on the rocks and metallic deposits of the Grand Duchy of Luxemburg, published in the "Berg. u. Huettenm. Zeitung," 1873, Nos. 4, 6, and 12, we extract the following data as containing valuable information on the nature of the iron ores of this country.

IRON ORES OF THE OLDER OR PALEOZOIC FORMATION.

In the very north of Luxemburg, close to the Belgian frontier in the Canton Cleaf, near Niederbesselingen and Goesdorf, there are found irregular deposits of hydrated oxides of iron, generally containing much quartz and very varying in their percentage of metal; although close to the northern railway, these iron ores have not as yet been utilized owing to the enormous and cheaper supply of ores from the oolitic formation.

IRON ORES OF THE LIAS FORMATION.

Clay ironstones are found at Schouweiler, running westwards over Garnich and Fingig across the Belgian frontier—they are only about 4 ft. thick, and yield about 10 tons per 100 square yards. The upper portion of the deposits is richest in iron, and the ore, when smelted, produces a good pig iron; usually, however, it is employed in admixture with the so-called Minette. At the mine mouth the ore is sold at between 3 and 4 francs per ton.

IRON ORES OF THE OOLITE FORMATION.

The so-called "Minettes," which are by far the most important of the iron ores of this part of the Continent, pertain to this formation, and seem to have been worked for iron even in the time of the Romans. On the large scale, however, they were first utilized about twenty years ago by M. August Apetz, and at present about two-thirds of the ore extracted is smelted in the country, whilst the remaining third is exported to Belgium, or to the neighboring French and German furnaces. The entire minette deposits extend over an area of about 22,000 acres, of which about 2,500 acres can be worked open-cast. Usually 500 tons ironstone are estimated to the 100

square metres, and at present about three millions of tons are extracted yearly by a force of between 3,000 and 4,000 hands.

The minettes are all impure hydrated oxides of iron, resulting from the oxidation of carbonate of iron; and, from their losing, when calcined, both water and carbonic acid, they acquire a degree of porosity which greatly facilitates their reduction in the blast furnaces.

IRON ORES OF THE QUATERNARY FORMATION.

These ores, commonly called Bohnenerze (bean ore) in Germany, are similar to the bog iron ores, being limonites, that is to say, hydrated oxides of iron; the grains or pebbles of ore generally have become, however, so much more compact than those of bog ore, that when extracted from the diluvial deposits in which they abound, they can be separated from the earthy matter by washing with water. They are classed into two sorts, called respectively strong iron ores and weak iron ores, according as the pig iron produced from them is found to be more or less strong. The strong ores, which may very possibly pertain to the tertiary formation, have been for the greater part worked out in this district; they are paid for at the mines or washing places at the rate of 12 francs per ton, and occur as brown or black-brown grains or nodules of the size of a hazel or walnut, sometimes cemented together by an ochrey cement, as is also the case with the weak ores, which present all shades of yellowish brown, up to deep black-brown, and in both cases the specific gravity varies from 2.7 to 3.25.

ITALY.—During the year 1872, a royal commission has been inquiring into the condition of Italian industry, and has recently published the report of the results. With regard to the duty on the importation of pig or unmanufactured wrought iron, many manufacturers examined desired it ei her abolished altogether, or reduced so as to be more in proportion to the duty on machinery and manufactured articles. Several of the engineering firms declared they could hold their ground against English competition, as, though fuel and iron were dearer, labor of excellent quality was vastly cheaper than in England In Florence, two of the witnesses, MM. Masson and Bozza, the former owner and the latter manager of ironworks, when asked whether it was more advantageous to smelt iron in Italy or import it from England, gave opinions, the first in favor of the importation if charcoal was to be used for smelting in Italy, whilst the latter maintained the reverse opinion, on the understanding that coal could be employed. M. Bozza deprecated the proposal before the Italian Parliament, that the Elba iron mines should be put up to public auction, as its effect would be to throw them into the hands of English speculators, who would outbid all Italian competitors, and afterwards raise the price of ore so high as to make the economical smelting of iron in Italy quite an impossibility. M. Langer, to prevent the Elba ores being entirely lost to the Italian ironmasters, proposed that a heavy export duty should be imposed upon them.

NEW ZEALAND.—The Colonial Industrial Committee, which sat during the last months of 1872 at Wellington, have reported on the magnetic iron ores of the colony, and recommended the New Zealand Government, with a view to the encouragement of local industry, to offer a bonus of £5,000 for the production of the first thousand tons of good pig iron made in the colony, and of £1,000 for the first hundred tons of steel made from the Taranaki iron sands. At Wellington, a company has been formed, with a capital of £50,000, in shares of £10 each, to be entitled the New Zealand Titanic Steel and Iron Company; but as yet we have not received fuller particulars as to its objects than are conveyed by its title.

RUSSIA.—From the report of the mining department of St. Petersburg for 1870, which has reached us since the publication of our last foreign report, it appears that the total number of iron mines in work during that year in Russia amounted to 1,283, and that these gave employment to 164 smelting works containing 245 blast furnaces, besides which there were in operation 214 iron and steel works containing 448 puddling furnaces, 689 balling and heating furnaces, 495 steel cementing furnaces, 924 forges, 161 cupolas, and 93 air furnaces.

In the "Russian Mining Journal," 1872, we find a description of the Knonisky Iron Works, by M. Kalinin. This establishment belongs to the Countess Stroganov, and is situated in the Government of Perm, about 235 versts from the city of Perm. It was founded in 1859, when two blast

furnaces were erected, and 318 workmen were settled there, with plots of land given them. The mines are situated at a distance of from 10 to 50 miles from the works, mostly in a north-westerly direction, and produce spathic carbonates and brown hematites containing from 2 to 6 per cent. oxide of manganese, and averaging from 32 to 50 per cent. metallic iron. They contain but a trace of sulphur, and are considered to be quite free from phosphorus; the iron produced is of excellent quality.

The ores are roasted at the mines by wood before they are carried to the blast furnaces, where they are smelted by charcoal, made from pine and birch in the Tyrolese system of horizontal charring heaps. The blast furnaces are two in number, one of which "Sergievsky," with an internal capacity of 54.9 cubic metres (about 1,940 English cubic ft.), is blown with cold air through two open tuyeres, whilst the other, "Natalievska," is of 64 cubic metres, or 2,260 English cubic ft. internal capacity, and uses hot blast with two closed tuyeres. The blowing-engine has three cylinders, and is driven by a water wheel of 26 horse-power. These two furnaces, taken together, turn out yearly somewhat more than 6,000 tons of pig iron.

In the same journal we find a statement of the production of cast and wrought iron in the Ural district for each successive ten years, commencing from 1797, which is as follows:—

Years.	Cast Iron. English tons.	Wrought Iron. English tons.
1797—1807	103,794	61 613
1807—1817	101,743	64,405
1817—1827	110,268	73.681
1827—1837	121,760	80,441
1837—1847	136,028	94,044
1847—1857	160,055	113,648
1857—1867	201,303	129,380

In the year 1871, the mines in Finland yielded 1,121,197 tons of iron ore.

SPAIN.—In the "Mineria," 1873, No. 18, attention is directed to the numerous deposits of iron ores which occur in Catalonia, many of which might, no doubt, be utilized for the exportation of ores to France and other countries. In the Province of Gerona, the Valle de Rivas contains deposits of red and brown hematites, spathic carbonates, and the specular and magnetic oxides which occur in the lower silurian beds, and are of excellent quality. In the Catalan forges they yield 50 per cent. of wrought iron, which would be equivalent to about 60 per cent. pig iron if the ores were to be smelted in blast furnaces; being close to the new line of railway, now in course of construction from Grenollers to San Juan de Abadesas, fuel could be conveyed to the mines, and the ores smelted on the spot, for which water-power and other facilities are found in the immediate neighborhood. In other parts of this province the mines of San Lorenzo de la Muga, Massanet de Cabrenys, Darnius, Anglès, and la Sellera, are so far inland, and without means of obtaining wood or fuel, that they are not likely to come into work at present; but, on the other hand, those of Bagur, Puerto de la Selva, and Cadaquès, from being close to the sea, could no doubt be made use of for exporting ore to other countries.

In the province of Barcelona, besides the important deposit of magnetic iron ore at Figaró, large quantities of native oxides, associated with spathic carbonates of iron, and occurring either in the Devonian limestone or silurian slates, are found near the villages of Gracia, Gavá, Malgrat, and Santa Susana; those of Gracia are not more than $1\frac{1}{4}$ miles from the harbor of Barcelona; the ores from Gavá, although more distant, can also be shipped from the same port, besides having facilities for being shipped on the beach at Castell de Fels and Gavá. The magnetic ores of Figaró are only about 2 miles from Barcelona, on the immediate high road to Vich, and very soon may be transported by the San Juan Railway; the ores of Malgrat and Santa Susana are close to the shore at Malgrat, and also to the line of railway from Barcelona to Gerona.

In the province of Lerida, large deposits of red and brown oxides of iron occur in the Devonian formation of Bausen in the Valle de Aran and in the Silurian slates of Lins and Comadrins; more than 50 per cent. wrought iron is obtained from the ores in the common Catalan forges of the district; in Montanissele, Durro, and Tasel, the same ores, with more spathic carbonate and micaceous oxide, are seen forming lodes and masses in the silurian slates, and lastly in the cretaceous formation of Montsech, large deposits of micaceous oxide of iron, containing 65 per cent. of metallic

iron ore, are met with, which have been found of excellent quality and quite free from sulphur and phosphorus; should railway communication be opened from this district to France, these ores might assume considerable importance.

In the province of Tarragona, the native oxides of iron also occur in abundance at Los Borjas del Camp, Alforja, Albiol, Dosaigüas, Plá and Plá de Cabra, none of which deposits have as yet been explored to any extent, and with the exception of those of Los Borjas and Albiol, most of them would require new means of communication; these two last-mentioned could, however, be easily shipped from the port of Tarragona.

From Germany we hear that Krupp, of Essen, has purchased iron mines in the north of Spain, in order to supply his steel works, at Essen, with Bessemer pig iron.

Sweden.—The greatest activity has prevailed amongst the Swedish ironworks, and every nerve has been strained to increase the production of iron whilst the prices continue so high as at present. The great rise in price of Swedish charcoal pig iron during the last ten years, as compared with previous years, may be seen from the following figures, quoted from the "Svensk Boerstidning," the prices being nett cash at the ironworks:—

1863	£4	0	0	per ton.
1864	3	19	0	"
1865	3	19	0	"
1866	3	19	0	"
1867	3	16	0	"
1868	3	15	0	"
1869	3	13	0	"
1870	3	10	0	"
1871	3	12	0	"
1872	5	15	0	"
1873	9	0	0	"

and, as may naturally be expected, the prices of both ore as well as charcoal, more particularly the latter, have gone up enormously.

The Directors of the Central Swedish Iron and Steel Company have announced to the shareholders that the two new charcoal furnaces of unusually large dimensions, which have been building at Bjorneborg, are now nearly completed, and will be put in blast in June, for the production of Bessemer steel on the Swedish system, by running the molten charcoal pig iron direct from the furnaces into the Bessemer converters. The old charcoal blast furnace and the several forges have in the meantime been kept in full operation.

Tasmania.—It would appear from all accounts that the discoveries of iron ore in the north of this island are likely to be followed up energetically by the utilization on the large scale; preliminary experiments in smelting the ore have been made at Messrs. Drysdale and Frazer's foundry, at Melbourne, which are reported to have been highly successful, the pig iron made from it being declared of excellent quality, and a bell weighing 210 lbs., cast from it, has been forwarded to the Universal Exhibition at Vienna, along with samples of the ore. There appears to be two companies already formed for working the deposits, situated about five miles from Ilfracombe Bay, where there is good accommodation for shipping; the ore, which is brown hematite, is stated to contain between 60 and 70 per cent. of metallic iron, and is in great abundance; and as there is an equally abundant supply of wood in the immediate neighborhood for conversion into charcoal, it is believed that it will be more advantageous to smelt with this fuel in order to produce a superior class of iron and steel, as it is calculated that crude charcoal steel can be manufactured and delivered in London at £9 per ton. Some 2,000 to 3,000 acres of mineral land have been already taken up, and the Ilfracombe Iron Company, represented by Mr. J. Major, is making preparations to erect works on the banks of the River Tamar for the production of pig iron, and to construct a tramway about six miles from the mines. The original prospectus is said to have been withdrawn, and the property to be now in the hands of ten gentlemen (who have each subscribed £1,000), of whom all are Victorians, except one, who is a resident in Tasmania.

According to the latest advices from this colony, it appears that iron ores have very lately been met with in the south of the island also; the new discoveries are reported to be red hematite ores.

Turkey.—So very little is known respecting the manufacture of iron in Turkey, that the opportunity is now taken of extracting a few notes on this subject from a paper on the extraction of metals in Turkey, published by M. Fischbach, the engineer-in-chief of mines and roads at Salonica, in Asia Minor, in the "Berg u. Huettenman. Zeitung," 28 March, 1873.

The sites of iron smelting in olden times are recognizable by the great heaps of slag, seen for example between Pristina and Jilan, Egri-Pallanka and Giustendel, in the vicinity of Alendagh, near Constantinople, and many other places. The best, and in fact the only ore employed is the rich native oxide of iron in the form of iron sand, which is found in the sands of the streams and rivers where they enter the gulf of Alexandretta, and where their deposited matter becomes washed by the waves of the sea; this brownish or bluish black sand always contains particles of gold in fine dust or scales, for which in some localities it is worked by washing, and to the admixture of which, the extreme malleability and good qualities of the iron made from these sands have by some been attributed.

The largest quantities of such iron sands are obtained in the neighborhood af Sama-Kof, by washing the deposits of gravel, boulders, and sand, and this is also the case in the mountain range between Kirtschovo and Costivar, at Porétsché, Vrania, Sofia, Démirhissar, etc. The operations are of the rudest character, the banks or deposits of gravel and sand being broken down and pushed into an extremely strong current of water, flowing from a great height, from canals provided with sluices, by the aid of iron pointed poles and mattocks; the stones, earth, and sand, as well as the trees and other vegetation upon them, are carried away to the washing place, where the muddy water deposits the iron sands in long, but very narrow wooden troughs (from 15 to 18 ft. long and about 8 in. deep and wide), in which they are still further washed by the workmen, until the nearly pure iron sand remains behind, by which rude system very much of the iron sand itself is, as might be expected, also carried off with the water. The iron sand is then carried by donkeys and mules to the smelting places, situated in the woods amongst the mountains and in the neighborhood of waterfalls. Such washed iron sand is paid for at the rate of about fourpence English per hundredweight.

The reduction takes place in small furnaces, generally arranged in couples or fours together, which are from 8 to 10 ft. in height, 29 in. wide below, and 13 in. above; in these the damp iron sand is stratified with charcoal and a little green wood, and melted for eight hours, with the assistance of a pretty strong blast obtained from bellows worked by overfall water wheels; at the end of the eight hours, the bloom is broken out of the bottom of the furnace, when it is found to weigh from 175 to 225 lbs., and consists of a mass of extremely ductile tough iron, covered by a crust of slag and unreduced iron sand; this is dragged to some little distance from the furnace, and whilst still white hot is cut into about two equal pieces by naked workmen standing opposite one another, with axes, who accompany their blows by wild shouts for the purpose of keeping time and warning each other to guard against the glowing sparks thrown off at each blow; as the mass cools towards the end of the operation, the labor is extremely severe, especially in winter, where in these high mountains the ground is covered with snow and ice. The blooms thus halved are sent on mules to the hammers, where, after reheating, they are drawn out into flat bars of irregular dimensions. The hammers weigh about 5 cwt., have enormous wooden shafts, and are driven at 250 strokes per minute, by large overfall water wheels made of wood put together with iron nails. Notwithstanding the superiority of this native iron in quality, its irregular form, the taxes placed on its production by the Turkish Government, and the cheapness of foreign iron, on which a very low import of duty is now imposed, conspire to put an end to this industry except in the more remote districts.

United States.—All accounts combine in reporting the greatest activity as prevailing in every department of the iron trade, yet it appears evident that much remains to be done before the production of iron and steel in the United States can anything like supply the ever increasing home consumption; and notwithstanding the great resources of this country in both coal and iron ores, it seems probable that it will not be able to render itself independent of European importations for at least the next ten years to come.

An interesting and useful paper, entitled "An analysis of the cost and description of the methods of mining employed in the Marquette iron region, Lake Superior, Michigan," was read by Major J. B. Brooks, at the meeting of the American Society of Civil Engineers, March 6, 1872. It has subsequently appeared in the Transactions of the Society, and, as an example of a careful inquiry into the expense of each

item in the total cost price of the ton of these specular and magnetic iron ores, cannot too highly be recommended to a vast number of mine managers' attention, as it is too common to find that the total cost of the ore is alone known, without that of the detailed items, a knowledge which is of the greatest importance in order to become acquainted with those items upon which economies can be effected.

We have to thank the secretary for forwarding us the statistical report of the National Association of Iron Manu acturers, for 1872, the meeting of that body having been held on the 8th January, 1873, in Philadelphia; from this volume we venture to extract the following data, as they seem likely to interest many of our readers. Although the exact returns for the year 1872 had as yet not been received, many statements of the production of pig iron in the United States, for that year, had already been published, which the secretary of the Association criticises, and arrives at the conclusion that the total make had been generally over-estimated, and that the figures 2,250,000 tons would be the closest approximation to the true total make of pig last year in the United States; the value of this quantity is estimated at, in round numbers, £18,000,000; the total produc ion of wrought iron is put down in 1872, as 1,602,000 tons, of which quantity rails are estimated not to exceed 750,000 tons.

The Bessemer steel works in operation or in course of construction in 1872 were 12 in number, as follows:—

New York....John A. Griswold & Co., at Troy.
Pennsylvania. The Pennsylvania Steel Company, Harrisburg.
—— ..The Cambria Iron Company, Johnstown.
—— ..The Bethlehem Iron Company, Bethlehem (building).
—— ..The Edgar Thomson Steel Works, Pittsburg (projected).
—— ..The Sharpsville Bessemer Works, Sharpsville (projected).
Ohio.....The Cleveland Rolling Mill Company, Cleveland.
Illinois.....The North Chicago Rolling Mill Company, Chicago.
—— ..The Union Iron Company, Chicago.
—— ..The Joliet Iron and Steel Company, Joliet.
—— ..The Springfield Iron Works, Springfield (building).
Missouri.....The Vulcan Iron Works, Carondelet (projected).
Indiana.....The Indianapolis Rolling Mill Company, Indianapolis.

The total amount of pig iron converted into steel in 1872 by the Bessemer process in the United States was 125,361 tons; of the steel from this quantity 90,000 tons of steel rails are returned, the rest being employed for axles, tyres, etc.; pig iron for making Bessemer steel can now be obtained with facility from several districts in the States, but so much difficulty has been experienced in procuring a certain supply of spiegeleisen, that it is believed that this difficulty acts as a check to the extension of the Bessemer steel manufacture in the States; as yet, we do not hear of any attempts being made in the States to supply this want by a home-made article.

YEAR.	Pig iron, made by		Bituminous raw coal and coke.	Total.	Railroad iron.
	Charcoal.	Anthracite.			
1854	342,298	339,435	54,485	736,218	108,016
1855	339,922	381,866	62,390	784,178	138,674
1856	370,470	443,113	69,554	883,137	180,018
1857	330,321	390,355	77,451	798,157	161,918
1858	285,313	361,430	58,351	705,094	163,712
1859	284,641	471,745	84,841	840,627	195,454
1860	278,331	519,211	122,228	919,770	205,638
1861	195,278	409,229	127,037	731,544	189,818
1862	186,660	470,315	130,687	787,662	213,912
1863	212,005	577,638	157,961	947,604	275,768
1864	241,823	684,018	209,626	1,135,497	335,369
1565	262,342	479,558	189,682	931,582	356,292
1866	332,580	749,367	268,996	1,350,943	430,778
1867	344,341	798,638	318,647	1,461,626	462,108
1868	370,000	893,000	340,000	1,603,000	506,714
1869	392,150	971,150	553,341	1,916,641	593,586
1870	365,000	930,000	570,000	2,050,000	620,000
1871	385,000	956,608	570,000	1,900,600	775,000
1872	478,750	1,197,010	712,500	2,300,000	850,000

As a proof that, as mentioned in the commencement of this article, the iron manufacture of the United States has much to do before being able to supply the enormous demand in the country, a reference to the figures in the report, p. 198, will show that the consumption of iron of all kinds in the States for 1873, is estimated at no less than 4,311,500 tons, of which the railroads alone are put down for 2,478,500 tons, quantity considerably greater, than the entire production of pig iron of last year, which was only 2,250,000 tons.

From the various tables given in this report, the foregoing condensed statement has been compiled in order to show at a glance the total annual production of pig and railroad iron in the United States for each year since 1854, given in tons of 2,000 lbs. each.

The returns of the pig iron production already received show that last year (1872) Pennsylvania made 702,819 tons; Missouri, 126,713 tons; Michigan, 63,195 tons; Wisconsin, 67,000 tons; Maryland, 41,500 tons; Georgia, Alabama, and Tennessee, taken collectively, 26,000 tons; Ohio, 230,636 tons; New York, 159,164 tons; New Jersey, 64,413 tons; Virginia, 7,309 tons, while some of the other States have a still smaller production in 1872.

THE NOVA FRIBURG RAILWAY.

From the "Anglo-Brazilian Times," of Rio Janeiro, July 23, 1873.

On the 9th a trial trip, with 15 tons of cargo and 22 passengers, was made on the Nova Friburgo and Cachoeiras section of the Cantagallo Railway, of which section of 35.296 kilometres, 12.407 are on the Fell, commonly called the Mont Cenis, system, adopted in Brazil, for the first time, to overcome the difficulties of the ascent of the Serra de Nova Friburgo, which, though furnishing the most facile access to the rich municipalities of Nova Friburgo, Maria Magdalena, and Cantagallo, descends with considerable abruptness into the valley of the Bay of Rio de Janeiro, rendering the construction of an ordinary railway up it a matter of great cost and considerable engineering difficulty. Indeed, for many years the ascent of the serra remained the chief obstacle to the extension of the railway beyond Cachoeiras, until finally the province of Rio de Janeiro determined to accept the proposal of Dr. Bernardo Clemente Pinto Sobrinho to lease the Villa Nova and Cachoeiras section and to continue the line to its terminus at Cantagallo, for which purpose the province redeemed the first section from the Cantagallo Railway Company.

The second section, that of Cachoeira to Nova Friburgo, has been for some months ready for use, but the new engines which the Central Rail Company undertook to have constructed, were made too heavy, weighing 36 tons when loaded, 24 tons of which fell on the two hind wheels. Besides this, they had insufficient heating surface, and on receipt of their plans Dr. Bernardo at once sent an engineer to Europe to secure the three locomotives which had been used on the Mount Cenis Railway, now dismantled since the opening of the great tunnel.

The arrival of the new locomotives confirmed the fears entertained in regard to them, as the rails visibly yielded under the excessive load: although they drew 40 tons with ease, they could not keep up 10 atmospheres of steam for more than a kilometre. With them, however, the material of the line was brought up to the summit of the line. Finally two of the Mont Cenis locomotives arrived, and preliminary trials were made with them before that of the 9th, in which passengers were for the first time allowed to participate.

From Cachoeira to Boca do Mato, 7.540 kilom., is an ordinary railway, whose highest grades are 3.5 per cent. and sharpest curves of 80 metres radius.

From Boca do Mato to Alto da Serra, 12.07 kilom. the Fell central railway is laid throughout the whole section. The highest grades are 8.3 per cent. and the sharpest curves are of 40 metres radius. Of 4,400 metres of the extreme grade, 1,400 is in one stretch. But the conditions are much more favorable than those which existed on the Mont Cenis line, as this had 37.068 kilom. of continuous central rail line, with maximum grades of 8.3 per cent. and minimum curves of 40 metres, on 500 continuous metres of which the maximum

of grade and minimum of curve were conjunctly employed.

The section from Alto da Serra to the city of Nova Friburgo is of ordinary railway, and has the length of 15.349 kilom., with highest grades of 2.7 per cent. and sharpest curves of 60 metres radius. In these curves the central rail is laid, to give greater security, and the same is the case with the four curves of 80 metres radius in the first section.

The central rail rises 9 in. above the level of the outer rails. It is made double-headed, to furnish traction surfaces to two pairs of horizontal driving wheels, situated below the locomotive, which grip it between them with great force, being pressed on it by powerful springs whose action can be regulated at will. At both ends of the rail it is tapered, so as to enable the horizontal wheels to take or quit hold without jar or intervention of the engineer. All the cars and trucks are also furnished with horizontal wheels, to grip the central rail and guide them in the curves. The same rail serves to give friction surfaces to the brakes employed to moderate the descent.

At the first trial with the Mont Cenis locomotives a train weighing 16 tons was pulled up by one of them along the central rail section, 12.407 kilom., in 80 minutes, including 20 minutes stoppage for water and for a review of the engine. It descended in 50 minutes. On a second trial it took up 28 tons of rails in 96 minutes, including 34 minutes for three stoppages for water. Some slipping occurred, owing to the want of sand. The locomotive returned in 50 minutes. In another, the ascent, with a loaded train weighing 30 tons, was done in 90 minutes.

On the 9th a train of passenger cars with 22 persons and 15 tons of goods left Cachoeiras at 1 P. M., arrived at Boca do Matto in half an hour, left at 1h. 45m., arrived at Alto da Serra at 2h. 56m., including 10 minutes for water, left at 3h. 9m. and arrived at Nova Friburgo at 3h. 48m., where the inhabitants had turned out to receive the train and gave many cheers to Dr. Bernardo Clemente Pinto Sobrinho and to his Engineer-in-Chief, Mr. Borell du Vernay.

The Fell system has thus been successfully introduced into Brazil, and another part of the highlands which are so important a feature of the Brazilian territory, has been opened to the railway. The fact that the great majority of the traffic is downwards favors the employment of such lines to transmount the difficulties which the configuration of Brazil opposes to the communication of the highlands with the seaports.

The connection of Villa Nova with Nitherohy is nearly complete, only about two miles remaining to be laid with rails. Dr. Bernardo Clemente Pinto Sobrinho has arranged also for the lease of this connecting link with the capital of the province of Rio de Janeiro, and in a month or two there will be railway communication from it to Nova Friburgo, a place highly recommendable for its sanitary conditions and its excellent hydropathic establishment. The section from Nova Friburgo to Maria Magdalena is also well advanced in construction, and that to Cantagallo will not be long delayed.

THE INFLEXIBLE.

From "The Engineer."

The Devastation has never had a sea trial worth the name, but it is no longer an official secret that she is regarded as unseaworthy. We stated long since that it was probable the Devastation would never be severely, in other words properly, tested; and all that we have said has come to pass with great precision. Of course the Government can always say that they did all that lay in their power to try her, but the sea was obstinately quiet, and the winds perversely light during the whole time available for testing the merits of the ship. Such an argument is ingenious, plausible, and unsatisfactory. However, the result is, at all events, that the Devastation is considered, rightly or wrongly, to be so far unseaworthy that no more ships of her precise type are to be built. The Fury will resemble her in many respects, but there will be modifications, the exact character of which, even those engaged in her design are not supposed to know very well. A new ship, once more the typical ship of the

future, is to be constructed. She is to be called the Inflexible, and will not be at all like the Devastation. Mr. Goschen, and those in authority under him, are extremely reticent as to the design of this addition to our naval power, which is not to be completed until the year 1877. A few broad facts, however, have been stated, from which we gather that the Inflexible will have much greater beam than the Fury, that she will draw 3 ft. less water, and that her entire defensive armor, or the greater portion of it, will be concentrated on a central "box," or fort, in which will be mounted the heaviest guns which can be made. The Inflexible is to carry coal enough for a voyage of 3,000 miles, and, as far as we can learn, is to be supplied with a moderate, but practically efficient amount of sail power.

It is not difficult to elaborate from this bald statement, something like a general idea of what the new ship will be. As she is not to have a turret, but a square or rectangular box fort, it is probable that she will mount four 50-ton guns on Captain Scott's traversing turn-tables, the efficiency of which is well known to the naval world. As the armor is to be heavier than anything known before, it must be over 14 in. thick, and we shall be quite safe if we assume that its mean thickness on the broadside will be 20 in. What the backing will be remains of course an open question. So far it is all plain sailing, but the moment we take leave of the central box and its guns, we get into speculative difficulties. If the ship is not to be armored elsewhere, how is she to be kept from going to the bottom in an action? On these points we have, as yet, no information whatever, but the chances are that the vessel will carry a broad armor belt all round exept at the bow and stern; and that these last will be comparatively long and fine, and being divided from the main body of the hull by numerous water-tight compartments, no attempt will be made to keep shot and shell out of them, as the entrance of water will do no great harm. Indeed, it is easy to show that the weight of metal required to protect the bow and stern efficiently would be productive of greater evils than would ensue if these portions of the vessel were liable to be filled with water. On going into regular action, that is to say, when commencing a regular stand up fight or pounding match as sailors say, it might be good policy to admit water to these portions of the ship, so as to diminish the mark to be fired at by the enemy, and so far submerge the screws as to put them out of harm's way. We believe, in a word, that it would be mere waste of metal to attempt to arm the first and last 40 ft. or 50 ft. of the ship, which ought to consist merely of what we may term false structure, put on to improve the sailing, steaming, and seagoing qualities of the armored vessel, and for all other purposes quite useless. The design thus worked upon gives us a hull rectangular in deck plan, very wide, comparatively shallow and short, armored for its whole length at each side, while in the middle the side armor is carried up high enough to protect the guns. Forward and aft of the citadel we have an armor belt, say 9 ft. deep, and a plated deck; in short, a rectangular monitor plated all over and carrying a tremendous armament within an all but impregnable battery or casemate. On to each end of this monitor will then be fitted a comparatively light structure constituting a bow and a stern, and this structure will then be carried up in board at each end until it meets the central battery. To the whole very fair, if not excellent, lines may be given, and we shall have a roomy and comfortable vessel, with a moderately high freeboard, in which sailors can enjoy their existence; a ship which will sail and steam well, and be good to look at, and, in a word, in a thousand points superior to the Devastation or the Fury. The effect of the design is that in action the whole of the upper works forward and aft of the turret, and the bow and stern as far back and as far forward as the armor belt, are liable to be blown to bits. It remains to be seen, then, whether the monitor which would remain—the kernel from which the husk had been stripped off—would still be able to float, and to fight and to steer.

The answer must be in the affirmative. The destruction of the vulnerable portions of the ship would be very gradual. The loss of the upper works would be of no importance at all, unless there was a heavy sea on at the time the action was fought. But in a gale it would be so difficult to hit the ship with any shot likely to do harm, that it will be safe to assume that nothing is to be feared from this cause. As regards steering, the bow and stern would be so cut up into compartments below the waterline that the external skin would retain its

shape after a tremendous pounding with shot or shell, and the form of the hull would therefore be preserved so far intact that the ship would continue to steer very well. The introduction of a couple of very powerful centrifugal pumps would present no difficulty whatever; and by the aid of these the ship might be steered and navigated on Ruthven's system, even should both her twin screws be totally disabled, which is a very improbable event, as they would lie low, especially if water was taken in on commencing an action.

Such a ship as we have sketched embodies, we think, the best features of the compromise that must be adopted in modern naval architecture. We cannot have everything, but in this design we have everything that is essential. Such a vessel must be large; but it is ridiculous to imagine that 50-ton guns can be carried in small ships. The Inflexible will certainly not be small; and we believe that we have indicated what her principal features will be, broadly speaking, and it is some gratification to us to be able to add that in the main she will closely resemble a type of war-ship which we have long and persistently advocated in this journal. We hope that before designs are finally adopted for the armored sides and ends of the central battery, one or two cheap experiments will be carried out to decide upon the best system of constructing them. There is reason to believe that two 5 in. plates disposed with a vacant space of say 5 ft. between them would be quite as efficient in keeping out shell as two 8 in. plates superimposed one on the other, and brought into close contact by the bolts and nuts. The office of the first plate would be to break up the shell into fragments; the office of the second plate would be to keep these fragments out of the central battery. It is very remarkable that a scheme which promises so much and which has so often been proposed, has never yet been tested in practice on anything like a proper scale.

THE MEASUREMENT OF HIGH TEMPERATURES.

By RICHARD H. BUEL.

From "The Iron Age."

For the measurement of ordinary temperatures the mercurial thermometer is generally employed, because mercury retains its liquid state through a wide range of temperature (boiling at 662 deg. Fahrenheit, and freezing at—39.2 deg.), and, except near its freezing and boiling points, expands quite uniformly for uniform increments of heat. According to Reynault, the expansion of mercury is as follows:

Between	32°	and	212°,	1 part in	55.08.
"	212°	"	392°,	1 "	54.61.
"	392°	"	572°,	1 "	54.01.

And beyond these limits it seems difficult to find the law. For indicating lower temperatures, alcohol, which has never been frozen, is commonly employed—and the methods by which higher temperatures are measured will form the subject of this article.

An instrument used to show higher temperatures than can be registered by the mercurial thermometer is called a pyrometer. This name seems to have originated with Muschenbrock, in 1730. His instrument was a metallic bar, fixed at one end and acting on a scale at the other, showing approximately the temperature by its expansion. Many other pyrometers were constructed on this general principle, the chief differences being in the methods employed to read the scale. The expansion of a metallic bar is quite small for a considerable increase of temperature, and hence it is necessary to multiply this reading on the scale. This was first done by arrangements of levers and pulleys attached to the piece moved by the end of the bar, but it was found that there was so much lost motion that the readings were far from accurate. Lavoisier arranged a telescope which was caused to rotate as the bar expanded, and being directed to a distant point, magnified the reading to any desired extent. An instrument on a similar principle was made by Sixton for the United States Coast Survey, to determine variations in the length of the measuring rods. One end of the rod was firmly fixed, and the other came in contact with a compound lever carrying a rotating mirror. The reflection of the scale in this mirror was read by a telescope placed at such a distance

that one-twenty-five-thousandth of an inch increase in length was magnified to about one-fourth of an inch. With such an apparatus a change of length of one-hundred-thousandth of an inch could be easily noted.

The metallic bar described above was used by Brongniart in 1805 to determine the temperature of an oven in which porcelain was heated for purposes of ornamentation. He employed a bar of silver placed in the oven, the free end projecting beyond and marking its expansion on a scale. This pyrometer, though utterly unsuitable for purposes of accurate research, was quite well adapted for regulating the heat of the porcelain oven, where a temperature of about 1,100 deg. was required, and the work was injured if this temperature was much exceeded. Wedgwood's pyrometer, invented in 1782, consisted of a small cylinder of fire clay, flattened on one side, and a metallic scale having a graduated V-shaped opening. The cylinder was first placed in this scale, the flat side against one face of the opening, and was moved down as far as possible, and the reading taken. It was then heated in the medium whose temperature was to be ascertained, and again placed in the scale, where the temperature could be at once read off. Wedgwood observed the expansion of silver between 32 deg. and 212 deg., and compared it with that of the clay cylinder, assuming that 1 deg. on this scale was equivalent to 130 deg. Fahrenheit. It was found, however, that this device was exceedingly inaccurate. It was difficult to obtain clay that was uniform in quality—and cylinders made of precisely the same material gave very different indications, because some were pressed more closely than others. But the worst defect was, that a cylinder exposed for a long time to a low temperature contracted quite as much as one exposed for a short time to a high degree of heat. Its great inaccuracy will be made plain by the statement that Wedgwood determined the temperature of a blast furnace to be 32,277 deg.—while the highest theoretical temperature that can be produced by the combustion of carbon in air is about 4,500 deg.—and estimated the temperature of smelted iron (since determined to be about 2,800 deg.) at 20,577 deg.

The first pyrometer with any pretentions to scientific accuracy, was invented by Daniells in 1830. This consists of a bar of black lead grooved on one side. In this groove is placed a bar of platinum, one end of which bears against a shoulder in the groove, and the other end against a porcelain slip, called the index, which is free to move, but being secured to the bar of black lead by a friction band of platinum, remains in any position to which it may be forced. In using the instrument the platinum bar is adjusted to bear against the index, and a multiplying scale being applied, the position of the index is ascertained. The scale is then removed and the instrument is heated. After it has cooled the scale is again attached, and the amount of expansion of the platinum bar is denoted by the new position of the index. By observing the expansion between two known degrees of temperature a scale of degrees can be constructed. By this means Daniells determined the temperature of melted iron to be 2,786 deg., and of a blast furnace 3,300 deg. Fahrenheit—results which agree very closely with subsequent investigations.

In Regnault's experiments he used the air thermometer for the measurement of high temperatures. This consists of a tube having a bulb at one end and being open at the other. The bulb is filled with air or any gas whose coefficient of expansion has been accurately determined, and the tube is filled with a liquid, such as mercury or water, and inserted in a vessel containing the same liquid. As the air is heated it expands, and, if its temperature is raised sufficiently, will expel all the liquid from the tube. Knowing the expansibility of the gas, the degree of temperature can be determined by noting the position of the liquid in the tube. Platinum is ordinarily employed for the bulb and a portion of the tube, and glass for that part which is not exposed to great heat. In the hands of a careful experimenter very accurate results can be obtained with this instrument, but it is not well adapted for general use.

Gauntlett's pyrometer consists of two tubes or rods, composed of metals having different coefficients of expansion. The tubes are secured to each other at one end, and the other ends are left free. To the free end of one tube is attached a graduated dial plate, on the axis of which is a pointer with a pinion. The free end of the other tube carries a rack, which meshes into the pinion, and thus gives motion to the pointer when heat is applied. Within

certain limits these pyrometers can be made quite accurate and durable, and they can be exposed to high temperatures for long periods without injury. They are also exceedingly sensitive—and for these reasons they have been largely introduced. If exposed for any considerable length of time to temperatures greater than that of red heat, they take a set, and no longer act efficiently. As at present constructed they can be readjusted for slight variations arising from overheat or other causes. Mr. Bailey, of England, by an ingenious device, arranges these pyrometers to indicate higher temperatures than that of red heat—graduating them experimentally by exposing them to high temperatures for a few seconds only (which does not ordinarily cause a permanent set), and then when used to indicate these high temperatures, they are to be exposed for the same period of time.

There are at present three methods in use, among manufacturers and others, to determine high temperatures, such as those of furnaces and molten metals, which are worthy of being described somewhat in detail.

Prinsep's method, improved by Plattner, is based on observations of the melting points of alloys, the melting points of the metals of which they are composed having been accurately determined. Silver, gold, and platinum were recommended as the metals to be used in making the alloys, since they could easily be obtained in a comparatively pure state. In practice, however, it was found that silver absorbed oxygen during fusion, which disturbed its melting point—so alloys of gold and platinum are ordinarily employed. A cupel made of some refractory material is used, containing a number of minute cells, in which different alloys are placed, and by observing which alloys are fused, and which retain their solid state, the temperature is given by the following equation:

A=temperature of fusion of first metal.
B=temperature of fusion of second metal.
s=per cent., by weight, of first metal in the alloy.
S=per cent., by weight, of second metal in the alloy.
x=temperature of fusion of the alloy.

$$X=A \times s + B \times S.$$

There are some practical difficulties in the application of this method. In many situations it is hard to observe just when the alloy melts, and it has been found that the same alloys do not always melt at the same temperature, under precisely similar circumstances. Hence a number of observations are necessary to insure accuracy. As an illustration of the rule, we will give the result of an experiment at a furnace in Sevres. An alloy composed of 53 parts of platinum and 47 parts of gold, placed in the furnace, was thoroughly melted, while an alloy of 54 parts of platinum and 46 of gold, was just beginning to soften. The melting point of platinum is 4,591 deg., and of gold 2,016 deg.; and applying the rule, we find the temperature of the furnace to have been between

$$0.53 \times 4591° + 0.47 \times 2016° = 3381°$$

and

$$0.54 \times 4591° + 0.46 \times 2016° = 3497°$$

The method employed by Clement, Desormes and Schwartz, and afterward improved by Wilson, is based upon the different specific heat of bodies. A small copper cylinder containing water is used. This cylinder is surrounded by a casing of non-conducting material, and this latter by an air casing, for the purpose of preventing the escape of heat from the interior. A sensitive mercurial thermometer is placed in the water. This thermometer is fitted with a sliding scale, which is moved up when the mercury expands, and retains its position when the temperature falls. A small piece of platinum or fire clay, in the form of a cylinder or ball, is put into the water, and the position of the sliding scale is noted. (Platinum is generally employed for measuring the temperature of furnaces, and fire clay for molten metals, since platinum forms alloys if brought in contact with fused metals.) The ball is then heated, and plunged into the water, and the new reading of the thermometer is taken by observing the position of the sliding scale, when the required temperature can be obtained by the equation given below.

Q=the weight of water.
P=the weight of the ball.
s=the specific heat of the ball.
t=original temperature of the water.
T=final temperature of the water.
X=required temperature.

Then

$$X=Q \times (T-t \div (P \times s) + T.$$

There are several corrections to be applied, the nature of which will now be explained. The heat imparted by the ball

to the water does not measure its total temperature, some of the heat being absorbed by the mercury of the thermometer, by the glass of the same, and by the vessel containing the water, and some remaining in the ball. It will be convenient to apply these corrections, by adding an equivalent quantity of water to the actual quantity employed.

Let W=corrected weight of water.

Then $W = Q$ + weight of mercury × specific heat of mercury + weight of glass × specific heat of glass + weight of containing vessels × specific heat of material + weight of ball × specific heat of ball; and the corrected formula for the temperature will be:

$$X = W \times (T - t) \div (P \times s) + T.$$

An example will be given to illustrate this method:

Suppose a ball of platinum weighing 1,000 grains is immersed in 2,000 grains of water, the thermometer indicating 70 deg. Let the ball be then heated and immersed in the water, when the thermometer will indicate 97 deg. Suppose that the weight of the mercury in the thermometer is 150 grains; of the glass, 40 grains; and of the copper vessel, 800 grains, the specific heats of these materials being respectively, 0.033, 0.198, and 0.0952. The specific heat of the platinum ball is 0.0324, and applying the rules, we find:

$W = 2000 + 150 \times 0.033 + 40 \times 0.198 + 800 \times 0.0952 + 1000 \times 0.0324 = 2121.43$ grains; and

$X = 2121.43 \times (97° - 70°) \div (1000 \times 0.0324) + 97° = 1865°$.

From this we see that one degree on the thermometric scale corresponds to $1865 \div 27 = 69$ pyrometrical degrees.

In practice it will be found convenient to graduate the pyrometrical scale by experiment, noting the rise of the thermometer after the ball is heated in something whose temperature is known. Suppose, for instance, that a ball of fire clay is used, and that it is plunged into molten lead, silver and gold, whose melting points are respectively 630 deg., 1,873 deg., and 2,016 deg. If the temperature of the water were 70 deg. before each experiment, and after the three experiments, 81.1 deg., 102.5 deg. and 105.3 deg. respectively, it would indicate that one degree of the thermometer corresponded to (560 deg. ÷ 10.1 + 1,803 deg. ÷ 32.4 + 1,946 deg. ÷ 35.3) ÷ 3 = 56 pyrometrical degrees. Having thus ascertained the graduation, the instrument can be used for determining any other temperature, it only being necessary to multiply the degrees of heat imparted to the water in any case by 56.

We have described this method of measuring high temperatures at some length, because it is very convenient and quite accurate when carefully performed. In its use it is requisite to withdraw the heated ball from the heating medium and plunge it into the water as quickly as possible, and it might be well to enclose it in some good non-conductor before withdrawal.

Siemens' pyrometer, with a description of which we will conclude our article, is constructed on the principle that the pure metals offer an increased resistance to the passage of a current of electricity with increase of temperature. It is found that the resistance is about four times as much at a temperature of 3,000 deg. Fahrenheit as at 32 deg. The resistance does not increase uniformly, but follows a parabolic law, which has been accurately verified by experiment as high as about 1,800 deg. Beyond that point, although the curve is pretty clearly defined, more experimental research seems desirable. The equation of the curve, calling R the resistance, T the temperature, and A, B and C constants determined by experiment, is

$$R = A \times \sqrt{T} + B \times T + C$$

The apparatus consists of a platinum wire encased in a metallic tube, and wound upon a piece of fire clay, upon a helical groove. This is placed in the medium whose temperature is to be determined, and the ends of the wire terminate in a measuring instrument placed in any convenient position, and not exposed to the high temperature. An electrical current, generated by a small battery, is passed through the wire and the measuring instrument, deflecting a galvanometer needle, and giving a reading on a large scale. A table, which accompanies every instrument, gives the temperature at once from the reading of the scale.

This pyrometer can be permanently attached in any place where the temperature is not excessive, and a continuous record can be kept; but it should only be exposed to furnace heat for a short time, or the wire will become deteriorated.

Siemens' pyrometer is believed to be the most accurate instrument yet invented that is generally available for the measurement

of high temperatures. It will readily be perceived, however, that great care must be taken in the use of this apparatus, as well as with the others described, to insure precision; and the field is yet open for the invention of a pyrometer that can be placed in any situation of which we wish to measure the temperature, and will give reliable results without further precaution—in fact, an instrument that will occupy the same place in the furnace as a carefully constructed gauge does in the steam pipe. We have shown, however, that the desired result can be obtained, and how it can be obtained. The subject is one of much importance in many branches of industry, and we hope that these remarks will prove both interesting and instructive.

THE EFFECTS OF UNEQUAL HEAT ON THE COMPASSES OF IRON SHIPS.

From "The Nautical Magazine."

The mariner's compass is at once a source of safety and a source of danger. Where it is carefully watched, from day to day, and, if need be, from hour to hour, and where it is, as it were, kept under such strict and intelligent surveillance as shall enable the mariner to note its often varying deviation, and to apply the so-called "errors," as they arise, the compass is invaluable; but, on the other hand, where it is not watched, and where the causes of deviation are not understood, and where overmuch reliance is placed on it as a guide, it leads to danger. So long as the compass is treated by an intelligent and watchful master, as a useful and capable servant, it may be relied on; but if once confided in, without due intelligence, and without a knowledge of the effects of outside influences on it, the good servant becomes the bad master; the otherwise faithful guide becomes the false friend.

The correction of compasses for semicircular deviation is one of the greatest steps yet made towards the safe navigation of iron ships at sea; but, as that correction, good as it is, can only be accurate for the latitude in which it is made, even that correction becomes of less and less value to the mariner, as the ship gets into other latitudes, or becomes subject to new or varying influences. Hence it has always appeared to us that, as contributing to the safe navigation of an iron ship, a knowledge of the subject of compass deviation by the master, watchfulness, and a ready method of constructing a table or diagram of deviation, whenever an alteration in the compass is discovered, are, at least, as essential, if not more essential than absolute adjustment of the compass in port. The means for constructing a card of deviation would, of course, be of little value in the case of a ship running N. and S., and, consequently, rapidly altering her magnetic latitude. A compass book should always be kept and the deviation noted on every course steered, the amount of heel being always noted at the same time. In approaching the land, the table of deviation constructed on the voyage would be very useful, and the master ought never then to trust to the chance of observation for correction of each course steered. The work of adjusting in port can be done by skilled hands, and under conditions and influences of heat and cold well-known, and, therefore, may be done completely and perfectly. It may, however, on the other hand, be done by unskilled hands, and done imperfectly. The master of the ship has her under his command at sea, and is with her under varying conditions of atmospheric and other influences. It is, therefore, to the masters of ships, first, in seeing their compasses properly placed on board,—and, secondly, in watching the compasses, and being able to estimate and allow for varying deviations at sea, that we look for safety, rather than to minute arrangements in port.

In very many cases a master, or an officer, pleads as justification or extenuation of the loss of his ship, that the compasses were in error. This plea means, if it means anything, either that so-called "errors" existed, which he knew, and which he did not allow for; or that an alteration in the deviation had suddenly manifested itself, for which the officer of the ship could not account, or which he did not suspect, and of which he sometimes alleges he was unaware, until after the casualty had happened.

There is reason to believe that these so-called, and in many cases unknown, "errors," in the compass, are, in fact, more frequent than is generally suspected by mariners; and there is further reason to believe, not only that they are frequent, but that they are temporary and ever varying. If this be so, they must be a source of great danger to our iron ships, a danger that will increase in proportion as the existence of the "error" is unsuspected, and as power on the part of the master to detect its exact nature and amount is wanting.

We propose to call attention, not learnedly (for we do not launch into abstruse science), but generally and broadly, to a point that has suggested itself as being one source of danger: viz., the effects of unequal and varying distribution of heat over an iron hull at sea. This point may, possibly, already have formed the subject of learned papers; and if it has done so, we shall be glad if our readers will refer us to some of those papers; but whether it has or has not been treated of before, we can affirm that in no book that we have seen, published for every-day use by masters and mates, is the point pressed on the attention of the student, or held up to the mariner as being specially worthy of his earnest attention. This article is not intended to be deep or exhaustive, but purely suggestive. If it should contain anything worth consideration, and should be kindly received, the writer's object will be gained; if it should form the subject of hostile criticism, the writer will be satisfied, for he will rest in the belief that the subject is at least of interest.

To begin with, let us take three cases by way of illustration:

1. In an iron steamship going up the Red Sea, the master noted that the deviation in the evening was different from the deviation in the morning.

2. In an iron steamship in the Atlantic, making a passage from Liverpool to New York, the master found an alteration in his compass of 10 deg. in one hour. This happened when the ship was running along the shoals in 25 to 30 fathoms of water, between Georges and Nantucket Sudden change of deviation is common between Sable Island and Nantucket, though, except on this occasion, we have not heard of it exceeding 5 deg. It is partly occasioned by the rapid change in magnetic latitude, but in a great measure, we believe, by the alternate bands of warm and cold water.

3. In the case of an iron steamship in port, a deviation of 10 deg. was observed. In this case the sun was shining brightly on one side of the ship, and the other side was shaded.

How are these errors to be accounted for?

In "Bakewell's Electricity," page 229, is a passage as follows: "The development of heat being a characteristic phenomenon of an electric current, it was inferred that heat was also capable of developing electricity. The satisfactory proof of this inference is due to Professor Seebeck, of Berlin; and though this interesting branch of electric science has yet made no important progress, sufficient has been done to prove that heat, electricity, and magnetism are correlative forces. All that is necessary for the development of thermo-electricity is to heat any metallic body irregularly at its extremities." . . . "The quantity of electricity excited is, to a certain point, proportionate to the different degrees of temperature communicated to different parts of the same metallic bar, and does not depend on the absolute heat. Thus the application of ice will produce an electric current, as well as the application of heat, and by applying ice to one corner, and (heat) the flame of a spirit lamp to the other, at the same time, the effect is greatly increased."

It is not possible that we have in this a clue to the secret for which we are searching, and is it not possible that the fact of the City of Washington being out of her course, was owing to the action of unequal heat on her hull, and the consequent effect on her compasses? The iron ship steaming up the Red Sea would have the rays of the sun directly impinging on one side of her black iron hull in the morning, and on the opposite side in the evening. Both in the morning and in the evening the hull would be unequally heated, but in opposite directions, thus producing varying currents of electricity in the hull. May not this account for the difference in the deviation of the compass at evening as compared with the morning? The master of that ship has not been able to account for it to this day. The iron steamer in the Atlantic, to which we have referred, may have suddenly gone from warm water into cold water, or *vice versa*, and this sudden cooling or sudden

warming of the bottom of the ship, as compared with warmth to coldness, pre-existing in the whole hull, may it not have accounted for the alteration of 10 deg. in the compasses in one hour, referred to above?

Then, again, one of the most, if not the most, prolific source of danger is the heeling deviation, the amount of which is rarely determined by the compass adjuster; and masters who do not insist on ascertaining it for their own information, are subject to an unsuspected error, which, in iron steamships, with deck-houses, etc., of iron, is often enormous in its proportions; not unfrequently, if the compass is improperly placed, it may be half a point for each degree of heel, so that 15 deg. of heel, not uncommon in narrow ships grain laden, may mean seven and a half points; or, taking the heel 15 deg. each way, fifteen points. Few compass adjusters, if they had any option (and sometimes they have not), would place a compass so badly, but we are simply showing what may happen. We are not writing at random, but instancing what we are well advised has happened.

We may easily understand from this how it happens that nautical assessors often find that a ship has steered a course that ought to have taken her clear of the land, and are entirely unable to account for the stranding. Everything depends on the master of the ship, and if he is not alive to the numerous sources of error, no legislation in the world will help him.

We sympathize with the captain of the City of Washington, as we are fully advised of the great difficulty of safely navigating an iron steamship in the Atlantic, especially when nearing the American coast without observation. The anxiety of running through 1,600 miles of fog and the constant watchfulness entailed are not readily forgotten by those on whom they have devolved, and are altogether unappreciated by the outer world.

We began this paper by stating that we only wish it to be a modest attempt at raising discussion and spreading information. If there should be something in it, and we would timidly hope that there is, then we would suggest that more good may be done by calling the attention of owners and masters to these points, than in legislating for compass adjustment, and for the examination of compass adjusters.

STEAM ENGINE IMPROVEMENT.

From "The Engineer."

The title of this article is one which must be familiar to the readers of scientific periodicals, and many readers of "The Engineer" will be disposed to regard the subject matter of our discourse as trite, hackneyed, and worn out. We venture to think, however, that next winter, when coal has reached the price at which it is certain to be quoted, users of steam power will be disposed to regard the improvement of the steam engine as a matter of very vital importance, about which too much cannot well be said; and they may even feel some regret should they neglect to gather any crumb of information which it is in the power of others or of ourselves to afford them. Indeed, if proofs were wanting that the improvement of the steam engine is a subject of perennial, never dying interest, it would be afforded by a reference to the patent specifications which we publish every week. The number of patents taken out every year for improvements in the construction of steam engines and steam generators is relatively enormous; and one of the principal objects which we have in penning this article is to afford certain hints to inventors which may serve to direct their labors to a useful end. We propose, in a word, to indicate the nature of the improvements required in steam engines, and so to enable men coming comparatively fresh to their work to avoid waste of time and ability in carrying out schemes which are already old and well known, or absolutely useless as far as effecting any real improvement in the steam engine is concerned.

In approaching this subject it must not be forgotten that those who build steam engines must live by building them, and that economical steam engines—in other words, machinery of a good type—must cost more, and ought to cost more, than inferior engines. Strangely enough, however, we find that certain short-sighted steam users are actually more indisposed than ever to pay a proper price for good machinery since

the value of fuel augmented. They urge in too many instances the high price of fuel as a reason for not employing what they are pleased to regard as expensive engines, asserting that coals cost so much they have no money to spare for machinery. Of course this is not true of the entire steam-using, steam engine-buying public, but it is true of a considerable section of it; and the engineer who proposes to himself that he will set about improving the steam engine, and turning out something better than anything he or his firm have built before, shou'd weigh well the cost, and consider whether the game is worth the candle. It is expensive work educating the public until they can appreciate a good engine, and draw the distinction between it and a bad one. In certain districts, however, the engineer will find the education of the steam user already perfected, and he will see that it is impossible to sell a bad engine at any price. The engineer, therefore, should well consider what he is about before he rushes off to the Patent Office to secure protection for an invention which, however admirable, will not be appreciated by his clients.

With these words of warning we may proceed to consider the position of the engine inventor who is certain to find a ready and remunerative sale for the best engines he can produce, and this, we venture to say is the position of most marine engine builders at the present moment, and it is also the position of a very considerable number of the stationary engine builders who supply spinners and weavers. On the other hand, mine owners and ironmasters care but little for economical engines. They want strong machinery which will not break down, but they pay small attention to a saving of a pound or so of coal per horse power per hour. We have already referred to our patent lists, and we commend to the study of such of our readers as are interested in the matters of which we are writing that portion of these lists which refers to steam engines, boilers, furnaces, etc. They will there find that nearly all the patents taken out for improvements in steam engines are similar in character. They have, in a word, nearly all the same objects in view, and these objects are twofold—first, economizing the use of steam; and, secondly, regulating the speed of the engine. We shall neglect the latter subject at present. The former turns almost invariably on the construction of the valves or valve gear. The great idea with all inventors appears to be that, given a perfect valve gear every other good quality follows in its train. Now, we should be the last to dispute the advantage of a good valve gear; but we beg to impress the fact on our readers that, although good valve gear is essential to oconomy, it will not compensate for other defects, and so we come to certain propositions which should be generally understood.

The first of these propositions is that a great deal more steam is used by a steam-engine at each stroke than is theoretically necessary to develop the power actually exerted by the engine, and this is true, without qualification, of the best engine ever built. To make this proposition as clear as possible, we will illustrate it by a practical example. A steam-jacketed condensing engine with a vacuum of 27 in. and working up to 150 indicated horse-power uses 26 lbs. of steam per horse per hour. The initial pressure in the valve chest is 60 lbs. above the atmosphere, and the cut-off takes place at one-tenth of the stroke. Now, theoretically, one-horse power indicated should be supplied by this engine for every 11 lbs. of steam used per hour. The absolute theoretical initial pressure in the cylinder may be taken as 74 lbs. per sq. in. This gives an average pressure with a cut-off at one-tenth of 24.42 lbs., from which, making the deduction of 2.42 lbs. for back pressure we have 22 lbs. left as the average effective pressure. The piston speed of the engine to which we refer is 500 ft. per minute. Therefore each inch of piston does $500 \times 22 = 11{,}000$ foot-pounds of work per minute, and $\frac{33}{11000} = 3$ sq. in. of piston, which moving over 500 ft. per minute suffices to develop one horse-power. But 500 ft. per minute is 30,000 ft. per hour, consequently the hourly consumption of steam is in volume 1,080,000 cubic in., or 625 cubic ft. But we have stated that steam was cut off at one-tenth of the stroke, therefore the whole quantity admitted to the cylinder was but 62.5 cubic ft. per horse-power per hour, the pressure of this steam being, however, not 22 lbs. but 74 lbs Now steam of this pressure weighs per cubic ft .177 lb. approximately; from this it follows that the whole weight of steam required theoretically per horse per hour is but 11.06 lbs. The weight of steam actually used by the engine is, however, 26 lbs., or

more than double that theoretically necessary. The second proposition is, that nearly all this waste of steam and fuel is due to cylinder condensation. The engine we have named is actually at work, we know what its performance is, and have examined and calculated diagrams from it. The diagrams, if not faultless, are at least fairly good, the valve gear being of an excellent type.

Now it is such engines as these with which modern inventors propose to deal, and in almost every instance they assume that the only thing needful is a better type of valve gear. It is quite possible that if the valve gear of the engine in question were slightly modified, a saving of about one pound of steam per horse per hour would be effected; but this is practically nothing; an improvement which would do no more than this is not an improvement at all. We have quite enough of new types and modifications of valve gear. Our readers may rest assured that no advantage, as far as economy of fuel, is to be had by any so-called improvement on the Cornish cateract double beat valve; the cam puppet valve gear, such as that used by Fairbairn in his Saltaire engines; the Corliss gear, or, indeed, the secondary slide gear. As regards simplification of parts and reduction of first cost and wear and tear, there is still room for invention in valve motions, but nothing is to be hoped for in the way of economy. This being so, we would fain direct the labors of inventors into other and more promising channels. We have shown from actual practice that a very good engine, burning not more than 3 lbs. of coal per horse per hour, is actually using more than twice as much steam as it ought. Taking this engine as a point of departure, the man who wishes to improve upon it should endeavor to ascertain what is the cause of the loss, and until this be settled it is but waste of time to seek for a remedy. Inventors, however, as a rule, go very blindly to work. They assume, they seldom or never reason. They glance superficially at a difficulty; they do not endeavor to understand its nature. Watt would never have invented the condenser if he had not analyzed with the utmost patience the nature of the defects which it was intended to remedy, and so long as men continue to rush to the Patent Office the moment they hit on a device which is pretty and ingenious, without regard to its real fitness for its intended purpose, we shall have no further progress in steam engine improvement, at least in the highest and most important sense, namely, the economy of fuel.

Let us see, then, what direction invention should take. The example which we have cited affords an every-day lesson which he who runs may read. We have stated that the major part of the loss of steam to which we have called attention, is due to condensation in the cylinder; it is not all due to this cause, however, but so much of it is that we may for the present confine our attention to cylinder condensation alone. We may stop to point out here that if the engine worked with steam of 24.42 lbs. full stroke, that is, without expansion, the required theoretical quantity per indicated horse per hour would be about 34 lbs. In practice about 45 lbs. would be used. From this it would appear that the total quantity of steam by weight lost is practically independent of the rate of expansion—a fact explained by the influence of the jacket in the expansive engine. But it also appears that the ratio of loss increases in a very large propertion as we use higher measures of expansion. Returning now to the duty of the inventor who desires to improve upon existing practice, it is obvious that all his energies should be concentrated on preventing condensation, whether in the cylinder or in the jacket. The great want is a non-conducting cylinder. The operation of such a cylinder we have so frequently explained that we need not dwell on the matter here. Suffice it to say that by the aid of a perfectly non-conducting cylinder a greater amount of economy in the use of steam can be realized than is attainable by any other improvement of which the steam engine is capable. Is it, we ask inventors, absolutely certain that no other material can be used for cylinders than cast iron? The shell, indeed, may be of that material, but why should the whole inner surface be composed of metal which is an admirable conductor? The specific heat of lead, for example, is 22.6, while that of iron is 87.8. It may be assumed that a given thickness of metal in a cylinder must be raised at each stroke of the engine from some temperature t to some other temperature t^1, the quantity of metal will be augmented with its conducting power for obvious reasons. As lead is a worse conductor than iron we may assume broadly that the same

weight of metal will be raised from t to t^1 in a cylinder whether of lead or iron, but the weight of steam condensed to effect this rise of temperature, would be 22.6 in the case of the lead cylinder, and 87.8 in the case of the iron cylinder; for this reason lead would be four times as good a material for a cylinder as iron. Of course, a lead cylinder cannot be used, because it is too soft. It remains for the inventor to supply a material which, with the low specific heat of lead, shall possess sufficient hardness. It is clear, however, that there are large surfaces inside a cylinder never exposed to friction—the piston faces and cylinder lids. These might obviously be made of non-conducting materials with great benefit. Slate or enamelled pottery ware, for example, properly let into iron frames, would answer an excellent purpose, and they would tell to special advantage in the use of large cylinders with a short stroke. Again, it has been proved to demonstration, that the admixture of a small quantity of air with steam reduces its tendency to condensation. The use of air in combination with superheated steam has never yet been tried, except on a small scale by Mr. Parker. The advantage obtained was always great and obvious. The mixture of air with saturated steam is of very small value in practice, as the cooling of the steam results in dampness fatal to economy; very great benefit would follow on the injection of a small quantity, say ten per cent., of air into steam superheated to just such a point that the mixture of cold air with the steam would absorb or nearly absorb the superheat. Here is another field for the inventor to work in. Again, we may point out that much heat is dissipated by conduction from the cylinder to the bed plate—much more heat, and consequently steam, is wasted in this way, especially in small engines, than is suspected. Who will step in to prevent this waste?

We might extend this list of suggestions very considerably. We have said enough, however, we hope, to divert a little of the inventive talent of the nation from valve gear and governors to a path where it is more likely to achieve some really valuable results. Each improvement effected may promote the economy of the modern steam engine only a little, but a multiplicity of small savings will constitute an aggregate result on which an inventor may look with some pride and self-satisfaction.

ROCK-BORING MACHINERY.*

By Major BEAUMONT.

From "Engineering."

ON THE DIAMOND ROCK DRILL.

All new applications of machinery must, in these times of high-priced manual labor, have a peculiar interest, especially to such a body of practical gentlemen as that which I now have the honor to address; and the application of the diamond to the general purposes of mining will, I think, be allowed to be producing results well worthy of your attention. I appreciate fully the value of time, and shall, therefore, proceed at once to my subject, without making any introductory remarks, or referring to other means of doing the same work as is done by the diamond drill, except so far as may be necessary to explain the difficulties which it is asserted the system under discussion overcomes. The patents for the diamond drill are extensively worked by the Diamond Rock-Boring Company, the results previously obtained having removed the system from the category of experiment, and established it as a recognized and practical success. As a rule the company neither sell machines nor let them out on royalty, but contract, at a fixed price, for the execution of work. The business taken up by the company divides itself into four classes, in some of which a greater advance has been made than in others.

1. The sinking of boreholes for the purpose of testing or prospecting for minerals.
2. The driving of drifts, galleries, and tunnels, whether for mining, water-works, or railways.
3. The sinking of shafts.
4. The removal of subaqueous rocks by blasting.

All of you will have a general idea of how these operations are carried on. Still, in order to enable you to value the results

* Read before the Iron and Steel Institute at Liege.

obtained with the diamond drill, I shall recall the leading features of the position in which the application of machinery stands with reference to them.

1. Boreholes are ordinarily put down by giving a reciprocating motion to a chisel attached to the ends of rods, lengthened as the hole is deepened, the débris being brought up by means of shells or augers. This reciprocating motion is given either by manual labor or by power. A considerable difficulty and risk attends giving even a very moderately rapid reciprocating motion to a long column of rods, and to get over this difficulty, and facilitate their withdrawal, Messrs. Mather and Platt have constructed machinery whereby the cutting is done by the fall of a tool suspended from a rope, the great point of gain being the speed at which the necessary tools either for cutting or removing the debris can be lowered to their work and withdrawn. Attempts have, moreover, been made to apply a rotary motion to steel cutters, but even in soft rock the progress so obtained has been extremely slow, because no steel can be got which will withstand the abrading action of the rock.

2. Headings are ordinarily driven by drilling holes and blasting them. Machinery is applied to the drills by attaching them to pistons, actuated by compressed air in cylinders, a supply of water to clear the débris and cool the tool being used. The air is distributed by a valve or valves, driven by suitable mechanism, and a rotating motion is given to the tool to obviate its striking two blows in the same place. All the percussive systems of boring machines in actual use come under the above description, varying in the greater or less degree of mechanical skill with which the parts have been arranged.

Some machinery has been made which proposes to drive tunnels at one operation, entirely by machinery, and without the use of powder; but hitherto, so far as I know, only a few yards have been so driven experimentally.

3. Drills similar to those applied to tunnel driving have been used for shaft sinking, but only singly, and I have not heard of any case where the speed of the sinking has been notably increased.

*. The putting down of blast holes under water has always been considered a most difficult operation, because a blow cannot be struck under water, and I have never heard of machinery being applied in this direction at all. I saw on the Suez Canal rocks being removed by blasting, but the holes were put in by ordinary churn jumpers, worked from barges anchored in the stream.

The diamond drill is in principle quite distinct from any other system of holing rock, and works by rotation without striking a blow. Its action is rather that of abating than cutting, and the effect is produced by the sheer difference in hardness between the diamond and the rock it is operating upon. There is really no comparison between the hardness of the diamond and that of ordinary rock. If a diamond be kept rotating against a piece of sandstone it would cut a hole, say a mile deep, before it was seriously worn. It will be seen at once that if this wonderful resisting power be properly taken advantage of, a machine can be constructed that will hole rock without striking blows. This enables machinery of the simplest and most ordinary character to be used, and thus avoids those special difficulties that the mechanic must face when he is driven to utilize a large power in the production of percussive action; moreover, machinery can be applied in places where a recriprocating motion, if admissible at all, would present peculiar difficulties—such as making a hole under water, or putting down deep holes where, from the circumstances of the case, the cutter must be at a great distance from the source of power.

The diamonds that are used are not valuable gems, but carbonate, a substance that till lately had no commercial value, and was first introduced for the purpose of cutting other diamonds. It comes from the Brazils in considerable quantities, and though it has not yet been discovered in the Cape diamond fields, it is more than probable that it exists there, and, indeed, wherever the diamond is found. You will see that its appearance is much like that of a piece of coal, or dull jet, and as unlike as it is possible to be to its brilliant sister, the ordinary diamond; though chemists tell us that the two are identical in composition. I presume that one is perfectly, the other imperfectly crystallized; and if so, it is no doubt this very imperfect crystallization that gives to carbonate its value for my purpose, as it has no or next to no cleavage, and consequently does not split up and break in the way that a diamond or piece

of board would do. This last substance, of which I hold a sample in my hand, is an impure diamond, and would seem to stand half way between the brilliant and carbonate. According to the tables published in Ure's "Dictionary of Arts," the following are the different specific gravities and degrees of hardness of some of the hardest stones:

Substance.	Hardness.	Sp. Grav.
Diamond from Ormus	20	3.7
Pink Diamond	19	3.4
Bluish and yellowish	19	3 3
Ruby	17	4.2
Pale ditto from Brazil	16	3.5
Deep blue sapphire	16	3.8
Ditto paler	17	3 8
Topaz	15	4.2
Whitish topaz	14	3.5
Emerald	12	2 8
Garnet	12	4.4
Agate	12	2.6
Onyx	12	2.6
Quartz	10	2.7

Now, as there is plenty of corundum or rubies and sapphires in the market at mere nominal values as compared with those of carbonate, I thought they could be advantageously used in place of the latter, if only their hardness, as compared with the diamond, was anything approaching that which the tables led me to look for. On trying, however, both sapphires and corundum, I found the above proportions altogether wrong in point of hardness: they were nowhere near carbonate. The trial that I put them to was as follows: I set a piece of carbonate in a suitable holder, and held it against a grindstone; the carbonate turned the grindstone down. On trying the same experiment with the other minerals the grindstone wore them down. I am of opinion, therefore, that the diamond stands, in point of hardness or resistance to abrasion (if the two are not synonymous terms), at an enormous difference in advance of any other known material in nature, and this seems a most remarkable fact.

The application of the diamond to rock-drilling is worked out as follows: The stones are set in an annular ring, made of steel; they are fastened in by making holes as nearly as possible the size of the stones to be set, and then burying them,, leaving projecting only the amount necessary to allow the water and débris of the cutting to pass; the metal is then drawn round the stone so as to close it in on every side, and give as large a bearing surface as possible to resist the tendency of the stone to be forced out. I may here say the loss from breakage and from the stones being torn out is far more serious than from wearing; in fact, with good stones having good broad running faces, the mere wear is quite trifling. A stone breaking out is always a cause of damage to the others. The crown so set is attached to the end of a steel tube and kept rotating against the rock at some 250 revolutions per minute. Water is supplied through the hollow of the bar, whence it passes under the cutting face of the crown to the surface of the hole between the side of the latter and the outside of the boring tubes; the diamonds are thereby kept cool, and the debris from the cutting is washed away. The crown has to be kept pressed forward with a force depending on the nature of the rock to be cut, varying from 400 lbs. to 800 lbs., when the cutting is done at speeds ranging from 2 in. to 4 in. per minute. Granite and the hardest limestone are ready cut at 2 in. to 3 in. per minute; sandstones at 4 in.; and quartz at 1 in. per minute. These speeds can be increased at pleasure, but I give them as representing the rates at which the drills are ordinarily seen in practice.

On the table is a sample of pure emery, which was cut at the rate of 2 in. per minute, by a crown which I now hold in my hand and, which has bored through 6 in. of emery, 10 ft. of granite, and 95 ft. of hard sandstone; you will see that it is, so far as the diamonds are concerned, almost as fit for work as ever. The emery was cut out of a block put under the drill for experimental purposes, merely to show how great is the cutting power of the diamond. No rock is met with in mining that approaches emery in hardness, and, indeed, it would be a most difficult operation getting a hole put in it without a diamond drill.

The cutters travelling in an annular ring, it follows that a solid core is produced, an arrangement which, while it insures a minimum of work being done to make a given-sized hole, affords evidence of the strata passed through, a fact which is invaluable for certain applications. Having explained the crown, and the way in which it cuts, I shall now describe the machinery for utilizing it. 1. For prospecting. The drawings on the wall show two views of a prospecting machine, which are in all essential particulars the same as those now being used. The crown is screwed on to the end of steel tubes, which are successively lengthened as the hole is deepened,

the bars pass through a quill, and are gripped by a universal clutch which causes them to turn. Set screws on the top of the quill, steady them centrally at their upper ends; the quill is attached to a crosshead which slides between two vertical uprights, and weights are provided, working over pulleys by which the weight of the boring rods and crosshead are either increased or balanced, when extreme depth of holes are reached. The water is supplied by a force pump passing to the hollow bars through the union at the top of the quill. The other gearing about the apparatus is for raising and lowering the rods by power. It consists of a crab, and the lifting is done by means of a chain or rope passing over a pulley attached to shear legs across the hole. Two descriptions of boring tubes are used, one of which is more expensive than the other, but it is stronger, and at the same time being nearly flush on the outside, there is less risk of the rods jamming in the hole. Suitable tackle is provided for recovering the tubes when they break, and their hollow form makes them peculiarly easy to get hold of. It very rarely happens that any are permanently lost. The usual plan for lifting them is a taper tap which enters into the hollow, when a few turns suffice to get a firm grip.

The following table shows the dates on which some boreholes have been commenced and finished, and at this moment the Diamond Rock-Boring Company have over 30 machines either at work or about to commence, all of which are keeping fully up to the average of speed there shown.

STATEMENT

Showing Results obtained in some of the Boreholes erected by the Diamond Rock-Boring Company.

Locality.	What for.	Including getting Machinery on the ground, etc.		Actual Working Days.	Depth.		Remarks.
		Commenced.	Ended.		ft.	in.	
		1872	1872				
Girrick	Ironstone ...	1st October.....	30th Nov.....	54	902	0	Ironstone.
Moorsholme.	" ...	1st June	27th July	48	641	0	Ironstone found.
			1873				
Fishburn....	" ...	9th Nov.....	1st February	54	434	0	Coal found.
		1873					
Beeston.....	Coal.....	22d Feb.....	22d July.....	146	1008	0	Boring stopped on the 22d July.
		1872					
Chewton....	"	31st Dec.....	13th July.....	168	802	0	Boring stopped, and commenced in another place.
Wollaton....	"	1873 16th Feb.....	12th April	48	700	0	Commenced boring at 3e7 ft. below the surface of the ground. At 452 ft. passed a seam of coal 1 ft. thick: at 587 ft., a seam 6 in. thick; at 654 ft 6 in. a seam 4 ft. thick; and at 696 ft. through a a seam 5 ft. 10 in. thick.
Loftus	Ironstone ...	16th March.....	7th June.....	60	640	2	Ironstone found.
Ballymena ..	Coal.....	7th April.....	24th May	42	558	5	Nothing of value discovered.

The greatest speed attained was at Walluff, in Sweden, when 304 ft. 6½ in. were put down in one week.

I beg to read one among many certificates given, as I think that independent testimony of work actually done would be more satisfactory than any statement of mine.

"DUNDRAW, WIGTON, *June* 2. 1873.

"To Major BEAUMONT, R. E., M. P.

"DEAR SIR,—I feel that I should not be doing my duty to the Diamond Rock-Boring Company without adding my testimony as to the speed, excellency, and satisfactory manner with which your prospecting machine (No. 14) has done its work for me in Ireland. The borehole at Ballycloghan was commenced on the 7th of April and completed on the 23d of May, when a depth of 558½ ft. was reached, the whole of which was bored through a hard basalt and whinstone; during this time the machine was ordered to stop for a week for consultation with

another gentleman as to the advisability of going deeper; and allowing for this, and also Sundays and wet days, the daily average was within an inch or two of 20 ft. per day, and upon two days a depth of over 40 ft. each day was bored at one time, and in the presence of myself and several other gentlemen, the machine was boring at the extraordinary speed of 3 in. per minute (whinstone). An enormous quantity of core was daily extracted, and a complete section with perfect specimens was easily made. I may add I hope soon to require another machine or two to bore near here and in Scotland.

"I am, yours very truly,
(Signed) "R. A. Watson, C. E."

In soft strata, such as clay sand and alluvial deposit, the diamond system is of no use, and in such ground we always use the ordinary method of boring, turning to the diamond directly rock is reached. I may add, however, that the boring tubes, pump for supplying water, and the whole arrangement of prospecting machinery (irrespective of the diamond crown) is found of great use in getting through the soft, and fixing any necessary lining tubes. The actual speed of cut is the same as that previously quoted. There is, however, no advantage in cutting at so rapid a rate, as the time employed in actual boring is as nothing compared with that which is consumed in lifting and lowering the rods. Different distances are bored without lifting, according to the nature of the strata, and the necessity for obtaining information. The core, when formed, is passed into a core tube, and is kept from falling out on withdrawing the rods, by means of sliding wedges or clips which allow the core to pass freely up, but prevent its returning. The great advantage claimed for this system of boring consists in the speed obtained—work being done in less than months that formerly took years, and in the fact that sample cores of the strata passed through are obtained. To realize the benefits likely to accrue from these facts, one must remember the unsatisfactory evidence afforded by the powdered material brought up by the ordinary method.

Shafts have sometimes been put down in wrong places, and it is always of importance to know the strata to be sunk through, hence I think in future few pits will be sunk without first testing the ground by boring naturally. Unless such a speed as the diamond drill gives were possible, this course could not be followed, as though it might be well worth while to delay a sinking for a month or two for perfect information, it would be quite impossible to do so for the same number of years.

Turning to tunnel driving, you have before you a drill such as is actually used for that purpose, the leading features of which are that the drill shaft is screwed, and is driven by means of a longitudinal slot and feather. Gravity, as in the case of the prospecting perfecting machine, cannot be used; hence the advance is given by a nut driven by differential gearing. The feed would be positive were it not that the connection between the nut and the driver is by means of a friction brake around the former. The brake is held together by an adjustable spiral spring, and one of the lugs to which this spring is attached forms the driver of the nut; hence, when the power necessary to drive the nut exceeds the compression at which the spring may be arbitrarily set, the brake not only slips, but is actually taken off the nut. This arrangement has never failed in practice, and the drills may be relied upon with absolute certainty to relieve themselves whenever the pressure necessary to cut the rock exceeds a certain amount. Such an arrangement as this is necessary, since the rock is always variable in hardness. The drills, not being subject to the heavy blows which percussive action would throw upon them, are not more liable to deterioration than ordinary machinery. Some drills are now in good order, and at work, which were made three years ago, having since then cost next to nothing for repairs. Any number of drills that may be required are mounted on standards, which are connected with the air motor behind them, so as to be all driven from it. Each drill can be stopped and started independently, and as they work equally well, no matter how they may be angled, holes can be put in in positions where a miner would find it extremely difficult to work. The general arrangement of the company's tunnel-driving machinery is shown by drawings exhibited, and I would draw your particular attention to the method of fixing and removing the machinery. The jacks on the top of the standards fix the whole firmly in position, while on their being slackened and the standards tilted back, which is done by the machine itself, the whole is on wheels and

free to move. Twenty minutes suffice ordinarily to get the machine ready for work, and it could be done in less time. The compressor used to drive the company's machinery at Bristol, was a single cylinder, 20 in. in diameter, with a 5 ft. stroke. It was geared directly to a 24 in. steam cylinder, and was usually driven at 40 revolutions per minute.

In applying machinery to driving headings, and speaking only of those machines that operate by holing the face of the heading, and use explosives, there are two broad systems of working which have been followed. One has to endeavor to imitate the action of the miner who seeks to put in his holes to the best advantage, watching each shot and angling the next accordingly, and putting down at the most three or four holes before firing. The other system is to disregard the lay of the rock and the result of the previous firing, putting down such a number of holes as to make an absolute certainty of the rock being fetched to a given depth. All attempts to solve the question of tunnel-driving machinery by the first system seem to me to have failed, while the second, if fully applied, has always been successful. In practice the principal difficulty consists in bringing forward and fixing the machinery, and its subsequent manipulation, and as all boring machines once fixed put down their holes in a very few minutes, it follows that ease of management, and exemption from breakdowns, is a far more important element of success than mere rapidity of holing, which indeed all systems that I have seen possess. The following statement, taken from actual practice, will exemplify what I mean: In a gallery driven in compact mountain limestone by the Diamond Boring Company as an advanced heading for a tunnel in connection with the Great Western and Midland Railways at Bristol, thirty to forty shots were required to bring away the face, the holes being 3 ft. 6 in. deep, and an advance each shift of about 3 ft. 3 in. being obtained. Six drills were employed, their average speed of holing being 2 in. per minute, 30 holes at 3 ft.=90 ft. and six drills at 2 in. a minute=1 ft. per minute, or the complete holing was done in 98 min. =1 hour 38 min. of actual working. As a matter of fact it was very good work to get the lot holed in four hours. Supposing now the drills had been speeded to 3 in. per minute, or 50 per cent. quicker, the holing would have been done in a little over an hour, which would have shown a saving of only half an hour in four hours. My aim has, therefore, been to take a reasonable rate of speed like 2 in. a minute, and by so doing get certainty of obtaining a given result without break-downs, rather than trying for a *tour de force* in actual rate of cut. Exploding the holes is done successively, beginning with the central holes, which are angled, and progressing successively to the outside ones. At Mont Cenis the length of their machines precluded the possibility of angling, hence they were driven to obtain a first opening by putting down larger holes in the centre of the heading, which were not fired. The diamond drill being shorter, enables the drills to be angled, and the centre is blown without the aid of empty holes. I think it likely this is the cheaper plan, but I am not clear that the Mont Cenis engineers did not choose the more expeditious one, as the fact of angling means a loss of progress.

In comparing the diamond system with the Mont Cenis or other good system of reciprocating drill, mounted in such numbers as to have a proper command of holing power, I do not contend that there is much advantage in favor of the former in point of speed, as in either case the holes can be put in in any reasonable fixed time. I submit, however, that there is a certain gain, owing to the holes being true cylinders, and to the non-liability of the drills to break down, the machinery getting out of order being always a fearful source of delay. The great advantage claimed for the diamond system is its economy. No drills have to be sharpened, the plant is no more liable to get out of order than ordinary machinery, and the air in the motor can be used expansively, against which have to be set the wear of the diamonds, and the fact that the motor must be kept running whether 1 or 6 drills are at work. The latter disadvantages are, however, more than counterbalanced by the former advantages. The certificate of Mr. Brunlees, the engineer for the Bristol tunnel, is as follows:

"CLIFTON TUNNEL,
"WESTMINSTER, *May* 13, 1872.

"TO THE MACHINE TUNNELLING COMPANY:

"GENTLEMEN—Last week I had the pleasure of seeing your diamond borer at work in this tunnel.

"The material through which the tunnel is being made is hard mountain lime-

stone, with numerous joints filled with calc spar.

"The heading, which measures about 10 ft. by 8 ft., was previously driven by hand labor at an average speed of 9½ ft. per week.

"The boring machine, during its first week of actual work, advanced the heading 26 ft., though the men only made 8 shifts, the rate of progress per shift being 3 ft. 8 in. The result of the week's work was, therefore, nearly three times that attained by hand labor, and it is only reasonable to assume that when the machine men are fairly up to their work they will be able to bore 4 ft. per shift, and make 12 shifts per week.

"Hence there can be no reasonable doubt that the advance of the heading will become 48 ft. per week, or about 5 times that of hand labor.

"So far the diamonds show no symptom of wear, nor have any of them got loose in the setting.

"I am, Gentlemen, yours truly,
(Signed) "JAMES BRUNLEES."

SHAFT RIVETING.

The plans on the wall show the plant which is now about to be applied to sinking two pits, each 700 yards deep, for the Harris Navigation Company in South Wales. The shafts are not yet ready to receive the machinery, or it would long ere now have been at work. It will be seen the principle is the same as that which obtains in the tunnel-driving machinery, viz., a pair of girders or standards carrying as many drills as can conveniently be put on, which latter are driven by a double-cylinder compressed air engine, and each drill can be stopped and started singly. The system of working may be the same as that which I have described for tunnel driving, but as the diamond drill bores a hole equally well 100 as 1,ft deep, it is in contemplation to apply a new principle which the different circumstances which obtain in a shaft, as compared with a heading, render practicable. In place of drilling a series of holes 3 ft. to 4 ft. deep, the holes will be carried at one operation, say 100 ft. deep. The machinery will then be removed, and the blasting continued, until the whole depth bored has been reached. The anticipated advantages of this system are that the machinery will only require fixing once; and further (which is the main point), the operation of drilling can be carried on whether there is water in the shaft or not. Of course, 100 ft. is an arbitrary depth, and as the drill never gets out of truth, there is no reason why the holing 500 ft. deep should not be done from the surface, or so soon as the rock may have been reached. I quite anticipate that since the holes are all straight, or nearly so, it will occasionally happen that there will be no free side to blow to, or, in other words, the shaft will be fast; but in that case it will be easy to free it by putting in a few hand holes. I am given to understand that in America this system has been tried with very favorable results, and I hope shortly to test it fully. If successful, the enormous difficulty which dealing with water always presents will be materially lessened, and a considerable economy both of time and money will result in sinking shafts, as the most tedious part of the operation, namely, the holing, can be done by machinery from the surface, and irrespective altogether of the question of water. I shall have much pleasure in communicating to any one in Belgium interested in the subject, the results that may be obtained.

REMOVAL OF SUBAQUEOUS ROCK.

As regards the removal of subaqueous rocks, the drawings on the wall show the plant now being prepared to carry out a contract for the removal of rocks in the river Tees. The contract is between the Diamond Rock-Boring Company and the River Tees Commissioners. The work to be done consists of the removal of a long scrap of rock 600 yards long by 200 yards broad, with an average of 20 ft. of water over it at high tide. The rock is a terrible bar to navigation; it cannot be got away except by blasting, and to hole it by hand from a fixed stage would be a most costly and laborious operation. The plant consists of a barge supported on legs, adjustable to suit the irregularity of the bottom of the river. It is provided with an engine and boiler capable of driving 24 drills. That number of holes can be quite easily put down in a tide, as each hole 8 ft. deep will not take more than an hour to drill. The dynamite, which is the explosive to be used, will be introduced through the same tubes which guide the drills, and the holes will be exploded so soon as the barge has been shifted to a fresh scene of operation. The arrangements are such that the mines will be loaded and fired without the em-

ployment of divers. A single drill has already been used on the rock to prospect it, and a few shots fired, sufficient to show that the designed interval of 10 ft. from centre to centre of the mines admits of the rock being sufficiently broken up for dredgers to remove it, and at the same time the action of the drill under water was seen to be perfect. I give a general sketch of the machinery used for prospecting under water, and which was specially designed to meet the case of a rough sea; the single pile offers no resistance to the waves, and the power required to drive the drill can be conveniently taken from a barge or tug alongside by means of steam through a flexible tube. The Diamond Rock-Boring Company are offering to undertake the removal of the Gaunts Rock near Cork harbor, and other sunken rocks in seaways; and for this purpose the diamond drill is submitted to be unrivalled, owing to the fact of its working as well in water as in air, and its being independent of the distance at which the boring may be carried on from the machine itself. In the limits of such a paper as this it would be impossible to go more fully into detail than I have done. The whole and sole claim to merit on the part of the diamond rock drill consists in the fact that the use of carbonate enables rotary to be substituted for reciprocating motion. Percussive machinery must, from its nature, be expensive, and, in some cases, it is especially difficult, if not impossible, of application. I have not alluded to the use of compressed air in tunnel driving, which is common to any system; but I may be permitted to say that the value of compressed air as an adjunct to mining, is only now beginning to be properly recognized, and in proportion as it is introduced for underground winding, pumping, and other purposes, so it will facilitate the introduction of machinery for tunnel driving, as the compressing machinery necessary for setting drills in motion becomes a serious consideration when it has to be put down for that purpose only.

THE LATE GEORGE FRITZ.

By A. L. HOLLEY.

In the death of Mr. George Fritz, of the Cambria Iron Works, Pennsylvania, the iron and steel interest of America loses one of its most conspicuously successful engineers and managers.

It is not too much to say that Mr. George Fritz, and his brother, Mr. John Fritz (general manager of the Bethlehem Iron Works), have created the American rail mill, and established the success of the manufacture, chiefly in their radically new system of arranging and working three-high rolls, but largely also in every detail of plant—in heating apparatus, in adaptation of power, in finishing machinery, and in general arrangement; they have put their mark on every feature, not only of the rail mill, but of American rolling mills at large. And despite conflicting ambitions and rival interests, this distinction is generally and freely accorded to the Fritz Brothers; and their counsel, in all branches of the iron manufacture, has been universally sought, as of the highest authority.

A sketch of the life and labors of George Fritz cannot fail to be of interest, as illustrating the triumph of mind, not only over matter, but over adverse circumstances of many kinds.

This master in mechanical engineering—this manager whose product per unit of nominal capacity was the largest on record—this diplomatist who held in harmonious relations the largest organization of the kind in America—this practical workman in every branch of the iron and steel manufacture, and of mechanical construction—this well-read student in engineering, in architecture, art, and general literature—this man of the world who earned wealth and position—was a farm laborer until eighteen years of age; was then apprenticed to a carpenter, and was only forty-four years old at the time of his death. His early educational advantages were of the most limited and ordinary kind. Although of massive mould, he was never in thoroughly sound health; and to complete the catalogue of his embarrassments, his right hand was seriously maimed early in his professional career.

It is hardly necessary to say, in view of these facts, that Mr. Fritz was gifted by nature, not only with talents of a very high

order and great versatility, but with an enormous capacity for work, with vast perseverance, and with a high degree of manliness in his relations with men. Although reserved, and often severe, he was a true friend, especially to the young men and apprentices in the works, in whose training and advancement he took an unusual interest.

Carpentry and its literature at a very early day gave direction and intensity, in the mind of Mr. Fritz, to the pursuit of a vaster subject—architecture. It is probable that few amateurs, in its æsthetical department, have been better read or more keenly appreciative; and it is certain that in its engineering department few experts have been more successful. His practice in iron and timber trusses of large span, in stone and brick structures for every variety of mining and iron-making plant, and in now and then a timber Gothic church roof, or an elegant dwelling-house, was not small in amount or variety. His later buildings at the Cambria Works show how much of beauty in form and proportion are strictly compatible with perfect adaptation to uses, and how largely this element can be introduced without increasing cost.

The necessities of his situation led him, at the age of twenty three, to change the direction of his craft to pattern making, and this, in turn, opened to him a new department of construction equally congenial to his tastes. How far he was fitted to grapple with the problems of mechanical engineering, in their most difficult adaptations, he who runs may read, through the rolling mills of America. Yet it is not clear to those who best knew him that the pursuit of architecture, considering his extraordinary engineering capacity (so sadly needed by architects at large), and the purity of his taste, would not have led him into a more useful and certainly a more brilliant career.

It is comparatively easy to give an intelligible outline of the works of a master in any other profession. The engineering works of George Fritz were so numerous and so largly distributed, that a working drawing and specification of the American mill would be necessary to make them plain to the general reader.

Among the more prominent features developed by Mr. Fritz is the three-high mill, before referred to in these columns. In the old form of mill the grooves were in the middle and bottom rolls, so that the piece required turning over after each pass. Messrs. Fritz grooved the bottom and top rolls; the piece does not require turning over, as its two sides come alternately in the bottom of the groove of the top roll, and in the top of the groove of the bottom roll. They made grooving the top roll practicable by inventing the hanging guide. They also applied the carrying rollers, and re-arranged the whole system of guides and guards. They were the first to apply direct-acting engines to rail trains, and they constructed, above fifteen years ago, a well adapted type of vertical engine, which has since been largely copied, and the general features of which have entered into all modern mill engines. They also adapted quick-working engines to saws and finishing machinery. They reorganized the whole system of roll-turning for rolls, so shaping the grooves and proportioning the reductions that the number of bad rails was largely reduced. They overhauled the proportions of puddling and heating furnaces, and doubled their capacity.

Mr. George Fritz invented, and successfully worked, at the first trial, the feeding tables on three high mills for rolling Bessemer ingots, by means of which a man and two boys pass back and forth, turn over and finish, a 7-in. bloom long enough for three rails out of a 14-in. ingot weighing a ton, in from three to four minutes. These tables have been applied to every blooming mill in America.

At the time of his death he had nearly completed the designs for a pair of blast furnaces of the largest class, and of compound beam blowing engines, of novel form. His arrangement of this work, and his many new features in hot-blast stoves, and in details generally, will undoubtedly prove, like his other works, a mine of valuable information to the iron interest at large.

Mr. John Fritz took the management of the Cambria Works in 1854; George, who had by this time become an expert machinist, being his assistant. In 1860 John went away to build the Bethlehem Iron Works; George had by this time mastered the business at large, and up to the time of his death was in charge of construction and manufacture, in the largest rail works in America. He built most of the present structures, including the Bessemer Works, and was in charge of all the engineering of coal and iron mines, coke

works, blast furnaces, puddle and rolling mills, steel works, shops and transportation; and on nearly every feature of all this accumulation of plant and machinery, he left the impress of his ingenuity and judgment.

A remarkable feature of Mr. Fritz's engineering career—so prominent as to be generally noticed and commented upon—remains to be mentioned. His novelties always worked well at the *first trial*. Even so difficult a thing as the feeding into rolls of long, crooked, red-hot blooms of steel, weighing a ton each, by easily-controlled and durable machinery, worked successfully from the start, although durability was promoted by subsequent changes in proportions. Mr. Fritz always thought out his plans, in much detail, before putting pencil to paper.

The tribute of respect paid to Mr. Fritz, on the occasion of his funeral, by the profession, and by the representatives of the iron interest of America, and by the multitude of men with whom he had been associated—many of whom he had guided from their boyhood into positions of responsibility—was wide-spread and spontaneous. He was buried in Johnstown, among the scenes of his great labors.

PUBLIC WORKS IN JAPAN.

From "The Builder."

As a rule we do not get much information with regard to the public works of Japan, and therefore a little information upon the subject will be acceptable. From several official reports we learn that public works of various kinds are being actively carried out in different Japanese ports and cities. Thus, from Hiogo we learn that many public improvements have been and are being effected there. Last year the authorities published a new plan of roads for the town, which it was proposed to make on the slope of a hill behind Kobe; the work was commenced without any delay, and has since been carried on with considerable energy. In the native town of Kobe, moreover, a large number of old houses have been lately cleared away in order to make room for a new wide street, which is to extend the whole length of the town from east to west. In consequence of these improvements it is mentioned that a large increase has taken place in the value of land and house property. A great number of new houses have also been built of late in the town, and these, being on an improved principle of construction, are considered quite in the light of an architectural reformation. In Hiogo, too, building operations have been steadily carried on, and the largest warehouses and stores erected by foreigners in Japan have been built in that port. The streets which are regular, spacious, and excellently drained, have been macadamized; and large wells are being sunk in different parts of the town in order to give a more abundant and convenient water supply for the extinguishment of fires which may occur. Extensive new municipal buildings are also being built in a central position. They will consist of a municipal hall, which will contain accommodation for the municipal superintendent and the foreign police, a prison, and permanent sheds for the fire engines. The streets of Hiogo have hitherto been lighted with kerosene, but for the future, arrangements have been made to light them with gas. This work is in the hands of a company. At Osaka, too, a new municipal hall is now in course of construction; while the paving and draining of the streets have been completed, and the pier for ferry steamers has been considerably extended. In the native town old wooden bridges have hitherto been in existence, but these are gradually being replaced by substantial iron structures of a much improved character. Large additions have been made to the Imperial Mint buildings for the minting of copper coin, and for the manufacture of sulphuric acid. These additional works, however, have not as yet been completed. A new railway is in course of construction between Hiogo and Osaka, but its progress is very slow, and it is not expected that it will be finished until next year. A new line is also projected between Osaka and Kioto, and a large quantity of material has been prepared, but the order for its construction has not yet been issued. Telegraphs in this part of the country have, it is said, proved a very great convenience, and are much appreciated.

From Kanagawa we learn that public

works there have been actively carried out. Railway construction is a feature of these works, and last year witnessed the opening of the first railway in Japan. It is mentioned appropriately to this, that the cost of railway construction in Japan should be cheap, as money is easily procurable, material is plentiful and readily obtainable, and labor cheap. Preliminary outlay, such as parliamentary expenses, should be almost *nil*, and sums given as compensation are not likely to amount to much. The introduction of gas into Yokohama during the past year also deserves notice. The company is a native one, but the machinery and various materials were purchased in England. The gasworks are capable of producing 1,500 cubic metres of gas in twenty-four hours, feeding 2,500 burners. The consumption of coal is about 200 tons a month. The first section of the trunk railway intended to connect Yedo and Yokohama with Kioto, Osaka, and Hiogo, has been opened, and already attracts more traffic than can conveniently be carried on a single line of rail. Telegraphic wires have been stretched from Yedo to Nagasaki; but the line which is 830 miles long, is not yet pronounced in working order.

From another Japanese port (Hakodade), we learn that the local government has done a great deal of late towards improving the streets of the town. A destructive fire lately occurred there, and advantage was taken of this to straighten and widen the streets in that district, which in some quarters are now lighted with oil-lamps. A new style of building, similar to the European, has also been adopted in the construction of houses for the Government officials, and for a new custom-house. A new road has been constructed from Hakodade towards Sappara, extending over ninety miles. This road has been much wanted. A few miles from the port the site for the erection of an agricultural college has been prepared.

THE FUTURE OF THE IRON TRADE.

From "Iron."

Absolute sovereignty in the iron markets of the world has been so long enjoyed by England, that her awakening from a dream of fancied security has proved as sudden as it is unwelcome. Time, space, and fiscal barriers had been overcome. Far from dreading the competition of American producers, English ironmasters had solved the problem of underselling them on their own ground so long as the protection afforded by distance, and heavy duties, was neutralized by the high price of labor. From 2,033,137 tons, in 1868, the total export of English iron steadily increased to 2,680,723 tons in 1869, and 2,825,575 tons in 1870. In 1871 the export trade again increased to 3,169,219 tons, and, in 1872, culminated in a return of 3,388,622 tons. Up to the early part of 1872 the Americans were, beyond doubt, our best customers. The immense development of the American railway system, and the wholesale introduction of iron into construction of every kind, contributed to nourish a growing demand, and had we been able to supply iron at the prices of eighteen months ago, England would still have reigned supreme in the markets of America. But the influences which had long been in operation on the other side of the Atlantic began to make themselves felt here, and the effect of the enhanced prices of labor and fuel, and consequently of iron, has been not only to deprive the English ironmaster of his pre-eminence in the American market, but to call into existence a competitor in markets that we had hitherto safely counted upon as our own. The tremendous rise in the price of fuel during the present year has produced disastrous effects upon our American trade. In the first six months of 1872 the United States took 444,000 tons of iron of various kinds, while in the first half of 1873 only 228,000 tons were taken. It is true that the difference in bulk was in some degree compensated by an increase in value, and that a falling off of 216,000 tons only represented a decrease in value of £1,093,000, but other circumstances are calculated to deprive us of the comforting reflection that we have been well paid for what we have sold. As we have frequently pointed out, there is a certain point in the price of English iron at which competition with the American manufacturer becomes impossible. Until the recent reduction of £2 per ton in finished iron, this point had been far exceeded, and the diminution in

our trade had made itself severely felt. Even now our prices are too high. Pennsylvania bars can be sold for about £12 per ton in New York, a price which defies competition at our present prices, and threatens to exclude us from that market altogether, while the American manufacturers, with characteristic energy, are pushing their advantage in the South American, West Indian, and Canadian markets. So soon as their advantage presented itself, the ironmasters of the United States seized upon it and enormously increased the production of pig and finished iron with the effect of reducing the mills of South Staffordshire to half time, and inducing the entire cessation of work by some large companies in the north of England.

The reference of these disastrous consequences in the first place to the high price of fuel, and in the second to the high price of labor induced by strikes, is a short and easy method which only removes the difficulty a step further without solving it. Our great daily contemporary, the "Times," is apparently inclined to ascribe the difficulties of the situation almost entirely to the action of Trades Unions and the selfish policy of working men, who refuse to see anything but their own immediate or imaginary interest. We are told that, "higher wages and less work must, if continued, produce their natural consequences. We cannot idle and sleep, and waste money, and compete with other nations which are thrifty and active and intelligent." All this is undoubtedly true, but in common justice we must admit that coal is not the only article which has risen in price. Two of the most important necessaries of life have risen in almost equal proportion. Meat and potatoes, as every householder knows to his cost, are no longer to be purchased at the nominal rates of former days. The amount absorbed in the brute necessaries of existence exceeds by 50 per cent. that required a dozen years ago, and it is, therefore, only reasonable that wages should keep some kind of pace with the price of food. Adding to this the important truth that strikes and advances in wages have followed, instead of preceding, advances in the price of fuel, we arrive at the conclusion that some deeper causes than the barbarous expedient of strikes have contributed to the enhancement of the price of iron. Any attempt to elucidate the causes of this unwelcome phenomenon must be made on the somewhat circular theory, that iron and coal act and react on each other. It is incontestable that the output of coal has more than kept pace with the increasing requirements of iron, yet it is not impossible that the sudden requirements of an increased iron trade first started the ball which has been flung backwards and forwards from coal to iron and from iron to coal—attaining at each cast a higher flight. Figures are often deceptive, and the gradual increase in the production of pig iron at first sight fails to supply any reason for the enormously increased price of coal. In 1869 the total quantity of pig iron produced in Great Britain amounted to 5,445,757 tons, and in 1870 to 5,963,515 tons. Between 1870 and 1871 a greater increase took place, the output of pig iron amounting to 6,627,179 tons, supplemented by an advance in 1872 to 6,723,387 tons. A graduated increase like this fails to account for the sudden increase in the price of fuel between 1871 and 1872, followed by a leap in the price of pig iron from £4 6s. 7d. to £6 12s. in Wales, from £3 2s. 2d to £5 10s. in Scotland, and from £2 15s. 8d to £5 4s. 6d. in Cleveland. The sudden development of iron manufacture in Cleveland is by many high authorities held responsible for the heavy draught upon the fuel market; but, after all, the great development of the iron industry of England, and its consequent claim upon coal, are mainly referrible to the enormous foreign demand for iron immediately on the conclusion of the last war. At the prices then prevailing, England was the cheapest market for iron, and orders poured in for home and foreign consumption. Could the demand for fuel have been distributed over the whole country in equal proportions, it might possibly have been met without producing a sudden and enormous rise, but one of the conditions of profitable iron-making is the propinquity of an important coal field. Thus the first effect of the great demand for Middlesbrough iron was felt in the Durham coal fields in a proportion above the average draught throughout the country. In 1870, the Durham coal fields produced 16,075,000 tons, and the consumption for iron was 41.1 per cent., against an average percentage of the produce of the whole country of 31.01 per cent. employed in iron manufacture. In 1871 Durham raised 18,000,000 tons, of which iron took 41.8 per cent.,

while in 1872, the Durham output fell to 17,395,000 tons, and iron exacted 47.2 per cent. of this diminished product. So great was the demand at this period, that coal was actually imported into Middlesbrough from South Wales. In particular cases the percentage rose even higher, as in some of the collieries worked by Messrs. Joseph Pease & Co., iron took 58.8 per cent. in 1870, 60.6 per cent. in 1871, and in 1872, no less than 65.2 per cent. It is to these local and exceptional phenomena that the memorable game at battledoor and shuttlecock, by which the iron trade of the country has so severely suffered during the past few months, owes its existence. Coal was certainly not the first article affected, and iron-makers enjoyed a brilliant period of prosperity before the price of fuel overtook them.

In September, 1871, pig iron was selling at Middlesbrough for 50s. per ton. with coke at from 10s. to 12s., when iron rose gradually towards the end of the year to 64s., but—we quote Mr. I. Lowthian Bell—"coke was not affected up to that time." In January, 1872, however, pig iron rose from 64s. to 70s. 6d., and coke went up to 20s. In March forge pig rose to 84s., and coke to 25s. In April pig iron rose to 94s. and coke rose to 32s. 6d., the fuel now evidently gaining ground. Again, in July, forge pig rose to 110s., and coke rose to 37s. 6d. and 41s. In July, 1872, therefore, while pig iron had undergone an increase of 120 per cent. upon the prices of September, 1871, coke had risen about 350 per cent.. Without overlooking the strike in South Wales in 1871, it is as impossible, with these dates and figures before us, to assume that this extraordinary rise was due wholly and solely to agitation among the workmen, as it would be uncandid to deny the alacrity displayed by the working class in insisting on a participation in the general prosperity. But one important element in the great rise must not be ignored. At the period of sudden demand there was but little stock of coal in the country. For the preceding ten years the production of coal had been so little remunerative as to deter owners from laying down heavy stocks and incurring the serious loss entailed by deterioration. Three months sufficed to exhaust the stocks of coal and coke, and since January, 1871, the supply had been merely from hand to mouth. Coal-owners were surprised to find themselves at last making large profits, the men demanded and obtained their share, and the final result has been the inflation of fuel to an extent that has paralyzed the particular industry the exceptional conditions of which first called high prices into existence.

The truth of the *dictum* of the "Times," that "trade is a delicate thing, and very easily disarranged," is proved by the present state of the iron trade. A slight reduction in price—confessedly insufficient to place England in the favorable position once enjoyed by her—has yet proved itself equal to the production of an almost unhoped-for reaction. But it would be vain to expect the re-establishment of the English iron trade on its former secure basis until the price of fuel permits a corresponding reduction in the price of the metal, which, of all others, demands its profuse employment. In the present aspect of affairs it would be almost childish to hope that coal will ever again sink to a rate which paid workmen badly and masters not at all; but it is satisfactory to observe that the ordinary laws of demand and supply will assert their power before long. Throughout the length and breadth of the country innumerable collieries are being sunk, and the infallible rule that when a particular business becomes exceptionally profitable fresh capital and fresh competition will be brought to bear upon it, will, so far as it is possible to forecast events, be vindicated in the present instance. Within a couple of years, or less, the number of coal mines will be enormously increased. The question of labor will, however, continue to present a difficult aspect; and it will be of small avail that new collieries be opened if "tacit" arrangements among coal owners for "regulating," and among coal miners for "restricting" output, continue in force as of old. Coal masters, having reaped a rich harvest, will probably be less difficult to deal with than colliers, who will be sorely abashed when they find the glorious "champagne and perambulator" days coming to an end. Both have enjoyed—and will probably for a while longer continue to enjoy—a prosperous era, but the same law which brings competing capital into the coal trade will bring competing labor into the market also. Few persons would wish to see the coal trade depressed, but all would rejoice to find the just equilibrium arrived at, which—without

rendering coal-getting unremunerative—should permit the iron trade to exist.

The immense vitality of this latter industry is amply evidenced by the events of the last fortnight. A serious reduction in the price of iron failed to attract buyers, who evidently hung fire in anticipation of a farther fall, but this hope having proved baseless, orders are coming in with marvellous rapidity. Germany—by the abolition of the duties on pig iron—cannot fail to stimulate the blast furnaces of England; and America—moved by the tone of the market—has once more appeared as a purchaser. In the matter of railway *materiel* we still appear to hold our own, at least in value, as the exports of railway iron for the first seven months of 1873, reaches the figure of £5,604,841, against £5,344,727 in the corresponding period of 1872, and £4,510,093 in the first seven months of 1871. An enormously increased use of Bessemer steel is doubtless responsible for the prosperity of this particular branch. The durability and comparative cheapness of this fine material appear to have impressed themselves very thoroughly upon railway companies throughout the world, and it is in great measure owing to the strong and increasing demand for steel rails that the present activity of the iron trade is due, while new collieries again react upon the iron trade by a strong demand for heavy castings.

Thanks to Bessemer steel and the reduction of the German iron duties, English iron-masters may yet be enabled to weather the storm and carry on a steady business until the increased output and reduced price of coal shall once more restore the iron trade to its pristine prosperity, and reinstate England in her proud position as the undisputed mistress of the iron markets of the world.

FRENCH EXPERIMENTS ON THE STRENGTH OF STONE, BRICKS, AND CEMENT.

From "The Architect."

The French authorities have set themselves the useful task of trying the power of resistance of each kind of stone indigenous to the country, and tabulating the results in such a manner that every constructor may have a sure rule to guide him in the selection and application of his materials. This task is not yet completed, but the results already obtained are published, and cannot fail to be acceptable to every practical man as a contribution to the knowledge of the strength of materiale.

French building stones include limestone, which exists nearly all over the country, and is exported to a considerable extent; sandstone, found principally in the eastern provinces; granite, produced in Brittany and the centre of France; and trachytes and lava, confined to Auvergne.

CALCAREOUS STONES.

Limestone, which is the most plentiful, is also the most variable, as regards nature and quality, weight and resistance. A table has been drawn up showing these differences in the case of more than a thousand varieties, collected in all parts of France (the basin of Paris excepted, the stone found there exhibiting peculiar characteristics), arranged in the order of their power of resistance to crushing force, and from which the following general conclusions are drawn:

The weight of the calcareous stones employed as hewn stone varies from 1,400 to 2,800 kilogrammes the cubic metre, and their power of resistance from 20 to 1,200 kilogrammes per cubic centimetre, the kilogramme being equal to 2.204 lbs. avoirdupois, the metre to 3.280 feet, and the centimetre to .3937 lineal inches.

The harder kinds, which are cut with sand and water, weigh, with few exceptions, from 2,200 to 2,800 kilogrammes, and support a pressure of 220 to 1,200 kilogrammes; the softer kinds, which are cut with a toothed saw, weigh from 1,400 to 2,200 kilogrammes, and bear pressure to the extent of 20 to 200 kilogrammes.

Hard limestone is divided into two distinct classes—those which will take polish, and those which will not; the former (*pierres marbres*, as they are called) have a metrical weight varying from 2,600 to 2,800 kilogrammes, and some few examples are even heavier. The most resisting are those which have an imperceptible or finely crystalline grain, like the marbles of Belgium

and the North of France, the *choins* of the Ain and of Savoy, and the "cold stone" of Provence; these rarely weigh less than 2,700, and sustain often more than 900 kilogrammes. In the second rank come certain compact calcareous or suboolitic stones of Burgundy, Franche-Comte and some lacustrine varieties, such as those of Chateau-Landon and Gannat, of which the resistance varies from 700 to 900 kilogrammes, and the weight from 2,600 to 2,700.

The marbles, properly so called, used for decoration and statuary, offer the smallest resistance for the greatest weight: thus the white *saccharoide* marble of Saint-Beat, which weighs 2,741, has only a resisting power of 552 kilogrammes.

The hard limestones, not susceptible of polish, have a resisting power of 200 to 800, and weigh 2,200 to 2,600 kilogrammes. In a first category, with 2,400 to 2,600 kilogrammes weight, and 600 to 800 kilogrammes resistance, are placed the true lias, very homogeneous and finely grained, fit for pavement such as those of Lezinnes, Maningben, and Chandolin, and the subcompact varieties, some of which, like the fine white stone of Echaillon, near Grenoble, the lacustrine limestone of Vendome, and the hard oolite of Saint-Diziers, near Belfort, susceptible of receiving a half polish, form the link between stone and marble.

The hard stones with a less compact grain, which are employed for foundations in buildings of minor importance, form a second class, with a resistance of 360 to 600, and a weight of 2,000 to 2,500 kilogrammes; of these are the grey rock of Burgundy, the hardest banks of Lorraine, of Pitou, and the Bordelais, and the greater part of the lacustrine limestones of the Beauce. In a third series are placed the varieties of less hard stone, which in public buildings are placed above the basement, and known as *bancs francs* in the Paris basin. They carry 220 to 350, and weigh generally between 2,200 and 2,300 kilogrammes; such are the *bancs ordinaire* of Euirlle and Lérouville in the Meuse of Rairères, Yonne, and Chauvigny, Vréune, and the harder of the *molasses* of the south.

The soft calcareous stones, as already stated, will support 20 to 200, and weigh 1,400 to 2,200 kilogrammes. They are divided into "half hard," which are cut with some advantage by means of the ordinary stone saw and sand, and are employed in elevations to the first floor, and into "soft stones" which are always cut with a toothed saw, and are only used for the walls of upper stories. The former, which, when their grain is fine, are called *bancs royals*, carry 100 to 220, and weigh 1,800 to 2,200 kilogrammes; the best known examples are the *bancs royals* of Tonnerre, Savonnieres-en-Perthois, of Allemagne near Caen, and of the Lourdines near Poitiers, which are sent to and beyond Paris. The soft stones proper will support only 20 to 100, and weigh from 1,400 to 1,800 kilogrammes; these are not so generally diffused through the country as the harder kinds, but they are largely worked, and include many distinct varieties. In the north the quarries of the Oise and the Aisne, opened in the eocene coarse limestone produce the *vergelée*, of which we shall have to speak presently. In the west is produced the *craie-tuffeau* of Touraine and the neighboring departments, of which the weight is, relatively, very low—generally between 1,250 and 1,400 kilogrammes, and having a resisting power of 30 to 80 kilogrammes; and beyond these the *bancs*, also chalky but wanting in tenacity, of the Charente, known as *pierres d'Angouleme*, which is sent to Bordeaux and to Spain, whose weight varies from 1.800 to 2,000 kilogrammes, and resistance from 65 to 110 kilogrammes. In the south-west are the coarse calcareous stones of the Gironde and the Dordogne, whose power of resistance falls below 20 kilogrammes; while their weight is above 1,400 kilogrammes and of which the best banks mny be regarded as hard stone.

Finally, in the south-west, the *molasses* of the basin of the Rhone, of which the closest examples figure at the head of half-hard stones, while those in the greatest use, such as those of Saint-Just and Saint-Restitut, near Saint-Paul-Trois-Chateaux are comprised within the restrained limits of 60 to 90 kilogrammes of resistance, and 1,600 to 1,800 kilogrammes of weight.

To indicate more precisely the relations which exist between the nature, the weight, and the resistance of calcareous stones, and to arrive at a complete resolution of the general problem in question, it will be necessary to introduce into the classes above indicated new subdivisions founded particularly on the exact geological determination of the beds explored; but the

present rough attempts at classification has a really practical interest.

LIMESTONES OF THE PARIS BASIN.

The experiments on the calcareous stones are completed by a brief account of the results obtained with those of the basin of Paris, which are almost entirely derived from the coarse eocene calcareous strata. The hard banks of this formation, which belong principally to the upper portion, are found always regularly stratified in beds varying from fifteen centimetres to 1 m. 20 c. in thickness, but the consistence of the stone varies to such an extent that even in a single block which seems to be homogeneous, the resistance often varies from one to three in amount. Here then arises a serious difficulty with respect to these productions of the Paris basin, for while the difficulty of working and sawing must be calculated after the most compact parts of the stone, the resistance can only be taken from the softer portions, just as a chain is no stronger anywhere than its weakest link. This serious difficulty causes the homogeneous rocks of the Jura, Burgundy, and Lorraine, to be used for the foundations of large edifices, bridges, and other important works in Paris.

Only one marble is in use from the Paris basin: this is the lacustrine calcareous production of Souppes and Chateau-Laudon, whose resistance is represented by 600 to 900 kilogrammes, and its weight by 2,400 to 2,500 kilogrammes. The hard lias of which those of Bagneux and Senlis are the types, are now very rare in the environs of Paris; those of Courville, Marne, and of Vendresse and Violaine, Aisne, alone need be cited. They weigh from 2,300 to 2,400 kilogrammes, and their power of resistance varies between 400 and 500 kilogrammes. The less hard lias of the Carrieres, Saint Denis and Jerusalem, Seine and Oise, the fine stones of Isle-Adam and Senlis have about the same weight, but a resistance of only 300 to 600 kilogrammes.

The hard rock, the working of which costs in Paris from 8 to 10 francs the superficial metre, is also becoming rare. The best is that of Saint Nom, near Versailles, of Laversine, of Villers-la-Fosse, near Soissons; of Bonneuil, and of Saint Pierre-Aigle, near Villers-Cotterets. Their weight is between 2,200 and 2,400 kilogrammes, and their resistance varies from 300 to 500.

The ordinary rock and the hard rock, or *bancs francs*, the working of which costs 6 francs, are exhausted in the plain south of Paris, but are found at Parny, Hameret, to the north of Soissons, at Saint-Leu and Saint-Maximin, near Creil, and at Ferse-Milon; their weight varies from 2,000 to 2,300 kilogrammes, and their resistance from 150 to 400. To these may be added the celebrated and always abundant stone of Saillancourt, which weighs 1,900 to 2,200 kilogrammes, and sustains a pressure of 100 to 550.

It will be seen from the above figures that the hard stone of the coarse calcareous beds of the basin of Paris cannot with safety be submitted to heavy loads.

The half-hard stones, costing 4 francs the metre for working, are known under the designation of soft rock, *francs bancs*, and hard royal; they are obtained also in the plains to the south of Paris, in the valley of the Oureq, at Saint-Maximin, Buty and Mery, on the Oise: their weights vary from 1,800 to 2,000 kilogrammes, and their resistance between 100 and 200.

The soft stones of the Paris basin are far more homogeneous than the hard, and resemble in this respect the stone of the other parts of France. They are divided according to their texture, into *vergeles*, *lam*, *bourdes*, *pierres grasses*, or *Saint-Leu-pierres-fines*, and *pierres-douces*. The finest and closest, which are known as *bancs royals tendres*, and cost for working 2 francs 75 centimes the metre, weigh 1,600 to 1,800 kilogrammes, and will support from 70 to 120 kilogrammes; they are mostly obtained at Cooflans, Sainte-Honorine, Marly-la-Ville, et Mery Seine and Oise, Saint-Maximin and Saint-Vaastles Mello, Oise, Crorey, Autresches and La Ferte-Milon, Aisne.

Soft stone, properly so called, costing 2 francs per metre for working, weighs generally from 1,400 to 1,700 kilogrammes, and will bear from 40 to 90. The best of the soft stones are the *vergeles*, much used in Paris, and exported to Belgium and Germany; they are produced principally in the same places as the *bancs royaux*, cited above.

It must be remarked that, as regards the Paris basin in particular, not only is the quality of the stone very different in different banks, but the consistency will often vary in the same bank within the limits of a quarry; experiments with these stones

therefore require to be made carefully and frequently.

SANDSTONES.

Experiments have been made with 120 samples of sandstone belonging to nearly all geological strata; two-thirds, however, were of the *vosgiens* and *bigarrés* of the eastern region of France, the only part of the country in which such stone enters largely into construction. The sandstone deposits, in fact, supply much less building stone than the calcareous strata, and present less numerous varieties; these varieties, founded partly in the coarseness of the stone, and partly in the nature of the silicious, calcareous or argillaceous cement which unites them, do not represent great differences with respect to weight and resistance, which arise principally from the greater or less quantity of the cement itself, or, in other words, on the porosity of the stone. It is only necessary to divide these stones into two grand classes—the hard, of which the weight varies from 2,100 to 2,500 kilogrammes, with resistance of 350 to 780, and the half hard and soft, which weighs 1,900 to 2,000 kilogrammes, and support 80 to 300. A very simple test shows the amount of porosity of sandstone; it consists in merely letting fall a few drops of water on a fresh fracture of the stone, if it be soft the water will be absorbed instantly, if hard the water will take at least a minute to disappear.

GRANITES.

Ninety specimens of granitic stone, principally obtained from the two great granitic regions of Brittany and the adjoining departments, and the central plateau of France, are reported upon, and those represent all the varieties of this kind of material used in public works.

The weight of granitic stone is comprised within the restricted limits of 2,600 to 2,800 kilogrammes per cubic metre, but this furnishes no indication whatever of the resistance to crushing power. This resistance seems equally independent of the nature and proportion of the crystalline elements of the rock, whether granite properly so called, syenite, or protogene. The apparent characteristics which allow of these materials being classified according to their value in construction and decoration are, first, their state of preservation, and secondly, the size of the crystals of feldspar and quartz. Two grand divisions are at once established, viz., hard granite, which is difficult to work, and always susceptible of polish, to which the name of granite-marble may conveniently be given, and granite which has undergone a change, which will not polish but work more easily, which may be called granite-stone.

The former, granite marbles, the only kind employed in important works and for decoration, form two distinct classes; one comprising the fine grained granite or *leptinites*, and the common granites, with middle-sized and regular grains, such as those of Blavet, in Morbihan, Vire, Calvados, Lavan, Loire-Inferieure, and the protegne of Epierre in Savoy; the crushing resistance of these materials varies between 1,000 to 1,500 kilogrammes. The second class comprises those with coarse grains, such as the porphyritic granites of the environs of Cherbourg and Brest, and the syenites of the Vosges, whose resistance varies between 700 and 1,000 kilogrammes.

The granite-stones are also divided into fine and coarse grained: the former, such as those of Durat, Haute-Vienne, and of Ussel, Correze, will only in general support 600 to 800 kilogrammes; those in which decomposition has but just commenced, although difficult to polish, will support as much as 900 kilogrammes. The large grained granites, in which the feldspar is partly decomposed, as at Llagonne in the Pyrenees, and at Pensol, Haute-Vienne, will only bear 400 to 600 kilogrammes per cubic centimetre.

OTHER VOLCANIC ROCKS.

The number of specimens of volcanic rock which have been experimented on is too small to class them otherwise than as *trachytes*, *lavas* and *breccias*. It must be remarked that, in these stones, there is an evident relation between their weight and power of resistance. The trachytes of Cantal and of the Haute-Loire weigh 2,180 to 2,600 kilogrammes, and support 360 to 900 kilogrammes; while the lavas, such as those of Volvie, Puy-de-Dome, and of Agde in the Herault, weigh 2,000 to 2,180 kilogrammes, and support 300 to 500 kilogrammes.

Experiments have also been made on some other stones of less value in construction, but presenting exceptional results, such as the basalt of Esselle, Puy-de-Dome, which supports a crushing force of 1,879

kilogrammes, the schist slate of Villepail, Mayenne, used for pavement, which supports 1,400 kilogrammes, the jasper-brèche of St. Gervais in Savoy, supporting 1,839 kilogrammes, and the green porphyry of Ternuay, in the Vosges, which will bear 1,363 kilogrammes; these two were employed at the new Opera House, Paris, the former for capitals, and the latter for shafts of columns.

CEMENTS.

A considerable number of experiments have been made with cements and mortars, but particularly with slow-setting cements such as "Portland," now largely used in port and river work. Trials have been made monthly for several years with different series of samples of pure cement and of mortars made with one part cement and two parts sand. The results are given in the following table.

Age.	Pure Cement.		Mortar.	
	Crushing Resistance.	Tensile Resistance.	Crushing Resistance.	Tensile Resistance.
	Kilogs.	Kilogs.	Kilogs.	Kilogs.
1 month	152	18	36	10
2 months	189	25	48	13
4 "	209	32	53	15
6 "	236	29	77	17
8 "	248	32	114	18
1 year.....	253	32	133	19
2 years.....	251	28	128	20

It is concluded from these experiments that the resistance of Portland cements, immersed in the sea, increases rapidly during the first six months, much less during the second six months, and that afterwards, for two or three years, it remains stationary, if it does not tend to diminish; and this applies even to the very best made cement, like that of Boulogne, the quality of which is declared to be quite equal to the best English Portland. These results, if well founded, are of a nature to shake the confidence generally entertained by engineers at present in the employment of stone-setting cements, for coast-work.

It is worthy of remark, moreover, that from the period of complete hardening the tensile resistance is about one-eighth of the crushing resistance in the case of pure Portland cement, and one-seventh in that of mortar containing two parts out of three sand.

BRICKS.

Not many experiments have been made on bricks, which, says the report, are not generally submitted to great loads in construction, and the manufacture of which, moreover, is constantly improving both with respect to composition and burning. The hardest bricks tried were made at Sarcelles. They carried when laid flat 400 kilogrammes per square centimetre, weighing 1,800 kilogrammes the cubic metre. Good hard bricks, such as those of Boisguillaume, near Rouen, weighed 1,800 to 1,900 kilogrammes, and supported 200 to 300. When well burnt the Paris bricks known as Bourgogne, weigh 1,700, and support 90 to 100 kilogrammes, and common bricks weighing 1,500 to 1,600 kilogrammes, will support from 40 to 60 kilogrammes. It appears from experiments that the tubular or hollow bricks so much used in construction offer, for like sections, a greater resisting power than solid bricks, which is explained by the fact that the greater surface exposed allows them to be more perfectly burnt.

EXPERIMENTS ON TWIST IN WOOLWICH ORDNANCE.

From "Iron."

The Committee on Explosives are about to conduct an experiment to ascertain whether the ever-changing angle of spiral in some "Woolwich" ordnance has the advantages which were claimed for it when introduced into the English service, eight years ago. At present hardly two natures of guns in the British service are rifled with the same angle of groove; and, consequently, even where the calibres are the same, the ammunition is not interchangeable. Out of about 25 natures of guns, 19 have grooves of a uniform angle throughout their length so that the rifling of the shot and bore correspond; while in 6 natures the projectiles are rifled at a fixed angle, and the grooves

at ever-changing angles, so that the gun and its shot can only correspond at one point in the bore. To this latter device an important addition has been recently made, the shot being rifled at two different angles so that the bore and shot may correspond at two points in the increasing spiral, viz., at the origin of the grooves and again at the muzzle.

All foreign countries employ, for their heavy ordnance, the uniform spiral in the gun, with long bearings on the projectile. America and France once tried the increasing spiral, indeed, we ourselves imported the idea from France; but both countries have long since abandoned it as an unmechanical application of force productive of suicidal results. General Gilmore, who commanded the artillery at the siege of Charleston, attributed the blowing off of their muzzles by 23 out of 42 Parrott guns to the increasing resistance offered at the muzzle by the changing angle of groove.

At Woolwich, several of the latest built guns have had uniform twists given them, including the 9-lb. and 16-lb. field guns, the Indian ordnance, the Palliser conversions, and the rifled howitzers recently introduced. Thus four-fifths of the various natures of British rifled ordnance, and the whole of foreign rifled ordnance, are furnished with uniform spirals. But, whereas all foreigners employ the longest possible rifle bearing in each groove, we alone use an extremely short rifle-bearing even with uniform spirals.

Whether the Woolwich grooves be cut with a uniform angle throughout the entire length, or at a constantly varying angle, the projectile is so devised that no portion of its surface shall touch the bore except the rifling agencies. These agencies, in both cases, consist of two gun-metal studs to enter each groove, which are wedged into undercut holes near the middle of the projectile. Nicely balanced on the two lower studs, nearly under the centre of gravity, and unsupported at either end, it is obvious that the resistance to escape due to the oblique movement of the axis of the projectile must be far greater than that which would be due to the angle of spiral if we could suppose the axis of the bore and shot to correspond vertically and horizontally during its passage out of the gun. The Woolwich projectiles are subject to both these resistances, but that due to obliquity of the axis must be much the greater than that due to rotation.

The advantage claimed for this peculiar system of balancing the projectile in unstable equilibrium is, that a short bearing of 1 in. in each groove for every weight and every length of shot can alone be employed in an ever-changing angle of groove. And this increasing spiral is supposed to relieve the initial or maximum pressure in the powder chamber by allowing the shot to slip away more readily from its charge. As shown in Captain O'Hea's experiments with "part rifling" in small arms, a shot which slips away easiest from its charge has the highest velocity and the least recoil, or powder pressure. And if the increasing spiral brought about this result in heavy ordnance, the increment of velocity and decrement of pressure would be good evidence of the diminution of resistance in the bore. But it was clearly proved, in 1865, that the ever-changing spiral gave a decrement of velocity, so that in two otherwise identical 7-in. 6 -ton guns, fixed with 115½ lbs. shot and 22 lbs R. L. G. charges, the projectiles both being balanced on short-bearing studs, "the blow struck by the one shot on leaving the muzzle would be to that struck by the other as 100 to 103." The actual loss was:

	Velocity.		Total Energy.
Uniform twist and studs	1465.0 feet	=	1712 foot-tons.
Increasing twist and studs.	1443.8 "	=	1656 "
Penetrating power lost by increasing resistance...	21.2 "	=	56 "

This decrement of velocity, with the increasing resistances of ever-changing angles of spiral, was subsequently shown in 8-in. guns of 9 tons, five rounds being fired from each form of twist with stud balanced shot of 179 lbs. and 30 lbs. R. L. G. charges. The mean results were:

	Velocity.		Striking Force.
Uniform twist and studs..	13 8.6 feet	=	2237 foot-tons.
Increasing twist and studs.	1303.3 "	=	2121 "
Penetrating power lost by increasing resistance...	35.3 "	=	116 "

How much greater the increment of velocity would have been had advantage been taken of the uniformity of angle in the spiral to support the shot on long bearings extending along the whole cylindrical portion of its body, was not then shown. But in 1864 two identical 7-in. 7-ton guns were fired under exactly similar conditions, except that the 110 lbs. projectiles were in the one case supported along their whole

cylindrical portions with iron rifle bearings, and in the other they were balanced on studs working in increasing spirals. The powder charges were 25 lbs. R. L. G., and the results were:—

	Velocity.	Striking Force
Uniform twist with Scott's long bearings	1583 feet	= 1908 foot-tons.
Increasing short-bearing studs	1526 "	= 1775 "
Penetrating power lost by short bearings and increasing resistance	57 "	= 133 "

Captain O'Hea's experiments with small arms rifled only at the muzzle show that increase of velocity is ever accompanied with decrease of recoil or powder pressure. And it might be expected that, in heavy ordnance also, the decrement of velocity might be a measure of the increment of powder pressures. But to make plain the part which the change of angle in the groove plays in resistance to escape, and consequently to rise in the powder pressures, the experiments about to be conducted by the Committee on Explosives should be so devised as to eliminate as far as possible every disturbing element except the special force under investigation. To do this the mechanical forces operating within the gun, between the shot and the bore, must be intelligently studied.

The recent mathematical researches of Captain Noble, R. A., of Elswick Works, claim, for the increasing spiral, that it diminishes the pressure in the powder chamber to the extent of .08 ton per sq. in.—such puerilities are the defendants of this system driven to. As to that portion of the bore which is traversed by the projectile, and which is the vital part of heavy Woolwich rifled ordnance, Captain Morgan, R. A., of the Royal Gunpowder Factories, points out that the total pressure required to produce rotation, should be divided over each square inch of the bearing surfaces to estimate the relative values of different forms of rifle bearings. According to Captain Morgan, a long iron bearing in a uniform spiral imposes nine times less strain upon each square inch of the groove than the "Woolwich" stud system. So that if 90 tons be required to rotate a 600-lbs. shot, the pressure per square in. would be only 2 tons with Scott's long bearing, instead of 18 tons. This is omitting the mechanical forces developed by the obliquity of the axis, and which Captain Morgan calls "knockings" against the side of the bore, which is invariably and exclusively the property of a system of balancing heavy projectiles in unstable equilibrium. Following Captain Morgan's method, and dividing the pressures required to produce rotation as calculated by Captain Noble, each square inch of rifle bearing, it appears, according to Captain Noble, that the maximum pressure on the stud is theoretically the same, whether it be employed in an uniform or in an increasing spiral. Thus the pressure per square inch on the rifle bearing in the grooves of an increasing spiral would be nine times more than that of the long-bearing system, instead of 10 times more, as calculated by Captain Morgan. Captain Noble's researches have been claimed by the apologists of the Woolwich system as favoring their views, yet he shows that, whether in an increasing or in an uniform spiral, the stud is theoretically at least nine times worse than the long-bearing system. We should be glad if the forthcoming experiments were directed not so much to compare the demerits of two bad short-bearing systems, and prove whether the 19 natures rifled on the one plan and the 6 natures rifled on the other, be worst, as to show whether a long rifle bearing would not be better than either.

To make the proposed experiments as to the relative pressures in the chamber when uniform and when increasing twists are employed, worth anything, the projectiles prepared for the uniform spiral gun, should have two additional studs inserted in them for each groove. One of these additional studs should be inserted in the rounded part of the inner extremity of the projectile so as to coincide with and support the flat part of the base, and the other should be added at the shoulders. With four hardened studs so placed in each groove, a long rifle bearing would be approached, and the centring of the axes might be accomplished, and thus a tolerably fair representation of the uniform spiral in its better applications would be imitated. By this means the oblique movements of the axis would be minimized, as in all long-bearing centring systems, and the powder pressures so registered would indicate what power was absorbed in rotating the projectile; and not what power is taken up in overcoming the resistances due to oblique movements. The latter resistances are essential to the ever-changing angle of spiral which necessitates the employment of a short one-inch bearing

in each groove. To apply to the uniform spiral that which mechanical necessities alone compel us to employ in an increasing twist, and then to measure the relative powder pressures, is utterly absurd, not only in a mechanical and scientific point of view, but in that of the practical gunner. We protest against this monstrous absurdity beforehand, because there are ignorant officials easily beguiled by philosophical artillerists who have acquired a knowledge of some mathematical formulas, who may become still more hopelessly confused than they are at present, as to the mechanical forces which injure every projectile in its efforts to escape out of the few natures of guns furnished with increasing spirals.

The addition of a couple of studs for each uniform groove in the projectiles used in the forthcoming experiment would cost very little, and could do no harm, while it would approximate towards the results to be expected from uniform twists properly employed. The experiment would then be a very valuable one Meanwhile it is satisfactory to find that, after eight years' controversy as to the influence of the increasing spiral or powder chambers, experiment is to be substituted for argument, and gunpowder for mathematics—mathematics, the value of which any well-taught school-boy may estimate when he knows that amongst the reasons assigned by the late ordnance select committee for preferring the French or "Woolwich" plan of rifling over five other competitive systems, is "a disposition to admit of the advantage of an increasing over a uniform spiral, which has been strengthened by the present trial. This advantage can best be realized with a short bearing on two points." How "two points" longitudinally separated several inches on the shot rifled at a fixed angle can be made to conform to an ever-changing angle of groove throughout its length, our artillery philosophers do not explain. To exchange such philosophy as has governed the rifling of our heavy ordnance for eight years, and landed us in such dire results, for intelligent experiment, would be indeed a public gain for which the country would be very thankful.

FUEL.*

From "Nature."

In accepting the invitation of the Council of the British Association to deliver an address to the operative classes of this great industrial district, I felt that I was undertaking no easy task. Having to speak on behalf of the Association, and in the presence of many of its most distinguished members, I am bound to treat my subject scientifically, but I have to bear in mind at the same time that I am addressing myself to men unquestionably of good intelligence, but without that scientific training which has almost created a language of its own.

It is no consolation for me to think that those who have taken a similar task upon themselves in former years, have admirably succeeded in divesting highly scientific subjects of the formalism in which they are habitually clothed. The very names of these men—Tyndall, Huxley, Miller, Lubbock, and Spottiswoode—are such as to preclude in me all idea of rivalry, but I hope to profit by their example, and to remember that truth must always be simple, and that it is only where knowledge is imperfect that scientific formulæ must take the place of plain statements.

The subject matter of my discourse is "Fuel;" a matter with which every one of us has become familiarized from his infancy, but which nevertheless is but little understood even by those who are most largely interested in its applications; it involves considerations of the highest *a priori* interest, both from a scientific and practical point of view.

I purpose to arrange my subject under five principal heads:—

1. What is fuel?
2. Whence is fuel derived?
3. How should fuel be used?
4. The coal question of the day.
5. Wherein consists the fuel of the sun?

What is fuel?—Some of you may have already said within yourselves that it is but wasted time to enlarge upon such a theme, since all know that fuel is coal drawn from the earth from deposits, with which this country especially has been bountifully

* Lecture delivered before the British Association at Bradford, by Dr. Siemens.

supplied; why disturb our plain understanding by scientific definitions which will neither reduce the cost of coal, nor make it last longer on our domestic hearth?

Yet I must claim your patience for a a little, lest, if we do not first agree upon the essential nature of fuel, we may afterwards be at variance in discussing its origin and its uses, the latter at any rate being of practical interest, and a subject worthy of your most attentive consideration.

Fuel, then, in the ordinary acceptation of the term, is carbonaceous matter, which may be in the solid, the liquid, or in the gaseous condition, and which, in combining with oxygen, gives rise to the phenomenon of heat. Commonly speaking, this development of heat is accompanied by flame, because the substance produced in combustion is gaseous. In burning coal, for instance, on a fire-grate the oxygen of the atmosphere enters into combination with the solid carbon of the coal and produces carbonic acid—a gas which enters the atmosphere, of which it forms a necessary constituent, since without it the growth of trees and other plants would be impossible. But combustion is not necessarily accompanied by flame, or even by a display of intense heat. The metal magnesium burns with a great display of light and heat, but without flame, because the product of combustion is not a gas but a solid, viz., oxide of magnesia. Again, metallic iron, if in a finely divided state, ignites when exposed to the atmosphere, giving rise to the phenomena of heat and light without flame, because the result of combustion is iron oxide or rust; but the same iron, if presented to the atmosphere—more especially to a damp atmosphere—in a solid condition, does not ignite, but is nevertheless gradually converted into metallic oxide or rust as before.

Here, then, we have combination without the phenomena either of flame or light; but by careful experiment we should find that heat is nevertheless produced, and that the amount of heat so produced precisely equals that obtained more rapidly in exposing spongy iron to the action of oxygen. Only, in the latter case the heat is developed by slow degrees, and is dispersed as soon as produced; whereas in the former the rate of production exceeds the rate of dispersion, and heat, therefore, accumulates to the extent of raising the mass to redness. It is evident from these experiments that we have to widen our conception, and call fuel "any substance which is capable of entering into combination with another substance, and in so doing gives rise to the phenomenon of heat."

In thus defining fuel, it might appear at first sight that we should find upon our earth a great variety, and an inexhaustible supply of substances that might be ranged under this head; but a closer investigation will soon reveal the fact that its supply is, comparatively speaking, extremely limited.

In looking at the solid crust of the earth, we find it to be composed for the most part of silicious, calcareous, and magnesian rock; the former, silica, consisting of the metal silicon combined with oxygen, and is therefore not fuel, but rather a burnt substance which has parted with its heat of combustion ages ago; the second limestone, being carbonate of lime, or the combination of two substances, viz., oxide of calcium and carbonic acid, both of which are essentially products of combustion, the one of the metal calcium and the other of carbon; and the third, magnesia, being the substance magnesium, which I have just burnt before you, and which, further combined with lime, constitutes dolomite rock, of which the Alps are mainly composed. All the commoner metals, such as iron, zinc, tin, alumina, sodium, etc., we find in nature in an oxidized or burnt condition; and the only metallic substances that have resisted the intense oxidizing action that must have prevailed at one period of the earth's creation, are the so-called precious metals, gold, platinum, iridium, and to some extent also silver and copper. But what about the oceans of water, which have occasionally been cited as representing a vast store of heat-producing power ready for our use when coal shall be exhausted? Not many months ago, indeed, on the occasion of a water-gas company being formed, statements to this effect could be seen in some of our leading papers. Nothing, however, could be more fallacious. When hydrogen burns, doubtless a great development of heat ensues, but water is already the result of this combustion (which took place upon the globe before the ocean was formed), and the separation of these two substances would take precisely the same amount of heat as was originally produced in the combustion. It will thus be seen that both the solid and fluid constituents of our earth, with the exception of coal, of naphtha (which is a mere modification of coal), and the precious

metals, are products of combustion, and therefore the very reverse of fuel. Our earth may indeed be looked upon as "a ball of cinder, rolling eternally through space," but happily in company with another celestial body—the sun—whose glorious beams are the physical cause of everything that moves and lives, or that has the power within itself of imparting life, heat or motion. The invigorating influence is made perceptible to our senses in the form of heat; but it is fair to ask, what is heat, that it should be capable of coming to us from the sun, and of being treasured up in our fuel deposits both below and on the surface of the earth?

If this inquiry had been put to me thirty years ago, I should have been much perplexed. By reference to books on Physical Science, I should have learnt that heat was a subtle fluid which, somehow or other, had taken up its residence in the fuel, and which, upon ignition of the latter, was sallying forth either to vanish or to abide elsewhere; but I should not have been able to associate the two ideas of combustion and development of heat by any intelligible principle in nature, or to suggest any process by which it could have been derived from the sun and petrified, or, as the empty phrase ran, rendered latent in the fuel.

It is by the labors of Meyer, Joule, Clausius, Ranken, and other modern physicists, that we are enabled to give to heat its true significance.

Heat according to the "dynamical theory," is neither more nor less than motion amongst the particles of the substance heated, which motion when once produced, may be changed in its direction and its nature, and thus be converted into mechanical effect, expressible in foot pounds, or horse power. By intensifying this motion among the particles, it is made evident to our visual organ by the emanation of light, which again is neither more nor less than vibratory motion imparted by the ignited substance to the medium separating us from the same. According to this theory, which constitutes one of the most important advances in science of the present century, heat, light, electricity, and chemical action are only different manifestations of "energy of matter," mutually convertible, but as indestructible as matter itself.

Energy exists in two forms, dynamic or "kinetic energy," or force manifesting itself to our senses as weight in motion, as sensible heat, or as an active electrical current; and "potential energy," or force in a dormant condition. In illustration of these two forms of energy, I will take the case of lifting a weight, say 1 lb. 1 ft. high. In lifting this weight "kinetic muscular energy" has to be exercised in overcoming the force of gravitation of the earth. The pound weight when supported at the higher level to which it has been raised, represents potential energy to the amount of one unit or foot pound. This potential energy may be utilized in imparting motion to mechanism during its descent whereby a unit amount of "Work" is accomplished. A pound of carbon then, when raised through the space of one foot from the earth, represents, mechanically speaking, a unit quantity of energy, but the same pound of carbon being separated or lifted away from oxygen, to which it has a very powerful attraction, is capable of developing no less than 11,000,000 foot pounds or unit quantities of energy whenever the bar to their combination, namely excessive depression of temperature, is removed; in other words, the mechanical energy set free in the combustion of 1 lb. of pure carbon is the same as would be required to raise 11,000,000 lbs. weight 1 ft. high, or as would sustain the work which we call a horse power during 5 hours 33 min. We thus arrive at once at the utmost limit of work which we can ever hope to accomplish by the combustion of 1 lb. of carbonaceous matter, and we shall presently see how far we are still removed in our steam engine practice from this limit of perfection.*

The following illustrations will show the convertibility of the different forms of energy. If I let the weight of a hammer descend in rapid succession upon a piece of iron it becomes hot, and on beating a nail thus vigorously and skilfully for a minute it will be red-hot. In this case the mechanical force developed in the arm by the combustion of carbonaceous muscular fibre is converted into heat. Again, in compressing the air in a fire syringe rapidly, ignition of a piece of tinder is obtained. Again, in passing an electrical current through the platinum wire it is directly converted into

* In burning 1 lb. of carbon in the presence of free oxygen, carbonic acid is produced and 14,500 units of heat (1 lb. of water raised through 1 deg. Fahr.) are liberated. Each unit of heat is convertible (as proved by the deductions of Meyer and the actual measurements of Joule) into 774 units of force or mechanical energy; hence 1 lb. of carbon represents really $14,500 \times 774 = 11,223,000$ units of potential energy.

heat, which is manifested by ignition of the wire, whereas the thermopile gives an illustration of the conversion of heat into electricity. The heat of combustion is the result of the chemical combination of two substances; but does it not follow from this that oxygen is a combustible as well as the carbonaceous substance which goes by the name of fuel? This is, unquestionably, the case, and if our atmosphere was composed of a carbonaceous gas we should have to conduct our oxygen through tubes and send it out through burners to supply us with light and heat, as will be seen by the experiment in which I burn a jet of atmospheric air in a transparent globe filled with common lighting gas; but we could not exist under such inverted conditions, and may safely strike out oxygen and analogous substances such as chlorine from the list of fuels.

We now approach the second part of our inquiry—Whence is fuel derived?

The rays of the sun represent energy in the form of heat and light, which is communicated to our earth through the transparent medium which must necessarily fill the space between us and our great luminary. If these rays fall upon the growing plant, their effect disappears from direct recognition by our senses, inasmuch as the leaf does not become heated as it would if it was made of iron or dead wood, but we find a chemical result accomplished, viz., carbonic acid gas which has been absorbed by the leaf of the tree from the atmosphere, is there "dissociated," or separated into its elements, carbon and oxygen, the oxygen being returned to the atmosphere, and the carbon retained to form the solid substance of the tree.

It is thus clearly shown that the sun has to impart 11,000,000 units of energy to the tree for the formation of 1 lb of carbon in the shape of woody fibre, and that these 11,000,000 units of energy will be simply resuscitated when the wood is burnt, or again combined with oxygen to form carbonic acid.

Fuel, then, is derived through solar energy acting on the surface of our earth.

But what about the stores of mineral fuel, of coal, which we find within its folds? How did they escape the general combustion which, as we have seen, has consumed all other elementary substances? The answer is a simple one. These deposits of mineral fuel are the results of primeval forests, formed in the manner of to-day through the agency of solar rays, and covered over with earthy matter in the many inundations and convulsions of the globe's surface, which must have followed the early solidification of its surface. Thus our deposits of coal may be looked upon as the accumulation of potential energy derived directly from the sun in former ages, or as George Stephenson, with a sagacity of mind in advance of the science of his day, answered, when asked what was the ultimate cause of motion of his locomotive engine, "that it went by the bottled up rays of the sun."

It follows from these considerations that the amount of potential energy available for our use is confined to our deposits of coal, which, as appears from the exhaustive inquiries lately made by the Royal Coal Commission are still large indeed, but by no means inexhaustible, if we bear in mind that our requirement will be ever on the increase, and that the getting of the coal will become from year to year more difficult as we descend to greater depth. To these stores must be reckoned lignite and peat, which, although not coal, are nevertheless the result of solar energy, attributable to a period of the earth's creation subsequent to the formation of the coal beds, but anterior to our own days.

In discussing the necessity of using our stores of fuel more economically, I have been met by the observation that we need not be anxious about leaving fuel for our descendants—that the human mind would surely invent some other source of power when coal should be exhausted, and that such a source would probably be discovered in electricity. I heard such a suggestion publicly made only a few weeks back at a meeting of the International Jury at Vienna, and could not refrain from calling attention to the fact that electricity is only another form of energy, that could no more be created by man than heat could, and involved the same recourse to our accumulated stores.

If our stores of coal were to ebb, we should have recourse, no doubt, to the force radiating from the sun from day to day; and it may be as well for us to consider, what is the extent of that force, and what our means of gathering and applying it. We have, then, in the first place, the accumulation of solar energy upon our earth's surface by the decomposition of car-

bonic acid in plants, a source which we know by experience suffices for the human requirements in thinly-populated countries, where industry has taken only a slight development. Wherever population accumulates, however, the wood of the forest no longer suffices even for domestic requirements, and mineral fuel has to be transported from great distances.

The sun's rays produce, however, other effects besides vegetation, and amongst these, evaporation is the most important as a source of available power. By the solar rays, an amount of heat is imparted to our earth that would evaporate yearly a lake of water 14 ft. deep. A considerable proportion of this heat is actually expended in evaporating sea water, producing steam or vapor, which falls back upon the entire surface of both land and sea in the form of rain. The portion which falls upon the elevated land flows back towards the sea in the form of rivers, and in its descent its weight may be utilized to give motion to machinery. Water-power, therefore, is also the result of solar energy, and an elevated lake may indeed be looked upon as fuel, in the sense of its being a weight lifted above the sea level through its prior expansion into steam.

This source of power has also been largely resorted to, and might be utilized to a still greater extent in mountainous countries; but it naturally so happens that the great centres of industry are in the plains, where the means of transport are easy, and the total amount of available water-power in such districts is extremely limited.

Another result of solar energy are the winds, which have been utilized for the production of power. This source of power is, indeed, very great in the aggregate, but its application is attended with very great inconvenience. It is proverbial that there is nothing more uncertain than the wind, and when we were dependent upon windmills for the production of flour, it often happened that whole districts were without that necessary element to our daily existence. Ships also, relying upon the wind for their propulsion through the sea, are often becalmed for weeks, and so gradually give preference to steam-power on account of its greater certainty. It has been suggested of late years to utilize the heat of the sun by the accumulation of its rays into a focus by means of gigantic lenses, and to establish steam-boilers in such foci. This would be a most direct utilization of solar energy, but it is a plan which would hardly recommend itself in this country, where the sun is but rarely seen, and which even in a country like Spain would hardly be productive of useful, practical results.

There is one more natural source of energy available for our uses, which is rather cosmical than solar, viz., the tidal wave. This might also be utilized to very considerable extent in an island country facing the Atlantic seas, like this, but its utilization on a large scale is connected with great practical difficulty and expenditure, on account of the enormous area of tidal basin that would have to be constructed.

In passing in review these various sources of energy which are still available to us, after we have run through our accumulated capital of potential energy in the shape of coal, it will have struck you that none of them would at all supply the place of our willing and ever-ready slave, the steam-engine; nor would they be applicable to our purposes of locomotion, although means might possibly be invented of storing and carrying potential energy in other forms. But it is not force alone that we require, but heat for smelting our iron and other metals, and the accomplishment of other chemical purposes. We also need a large supply for our domestic purposes. It is true that with an abundant supply of mechanical force we could manufacture heat, and thus actually accomplish all our purposes of smelting, cooking, and heating, without the use of any combustible matter; but such conversion would be attended with so much difficulty and expenditure, that one cannot conceive human prosperity under such laborious and artificial conditions.

We come now to the question—How should fuel be used?—and I propose to illustrate this by three examples which are typical of the three great branches of consumption.

a. The production of steam-power.
b. The domestic hearth.
c. The metallurgical furnace.

I have represented on a diagram two steam cylinders of the same internal dimensions, the one being what is called a high-pressure steam cylinder, provided with the ordinary slide-valve for the admission and discharge of steam into the atmosphere, and the other so arranged as to work expansively (being provided with the Carless

variable expansion gear) and working in connection with the condenser. I have also shown two diagrams of the steam pressures at each part of the stroke, assuming in both cases the same initial steam pressure of 60 lbs. per sq. in. above the atmospheric pressure, and the same load upon the engine. They show that in the latter case the same amount of work is accomplished by filling the cylinder, roughly speaking, up to one-third part of the length, as in the other by filling it entirely. Here we have, then, an easy and feasible plan of saving two thirds of the fuel used in working an ordinary high-pressure engine, and yet probably the greater number of the engines now actually at work are of the wasteful type. Nor are the indications of theory in this case (or in any other when properly interpreted) disproved by practice; on the contrary, an ordinary non-expansive non-condensing engine requires commonly a consumption of from 10 to 12 lbs. per horse-power per hour, whereas a good expansive and condensing engine accomplishes the same amount of work with 2 lbs. of coal per hour, the reason for the still greater economy being, that the cylinder of the good engine is properly protected by means of a steam-jacket and lagging against loss by condensation within the working cylinder, and that more care is generally bestowed upon the boiler and the parts of the engine, to insure their proper working condition.

A striking illustration of what can be accomplished by way of accuracy in a short space of time was brought to light by the Institute of Mechanical Engineers, over which at present I have the honor to preside. In holding their annual general meeting in Liverpool in 1863, they instituted a careful inquiry into the consumption by the best engines in the Atlantic Steam Service, and the result showed that it fell in no case below 4½ lbs. per indicated horse-power per hour. Last year they again assembled with the same object in view in Liverpool, and Mr. Bramwell produced a table showing that the average consumption by 17 good examples of compound expansive engines did not exceed 2¼ lbs. per indicated horse-power per hour. Mr. E. A. Cowper has proved a consumption not exceeding 1½ lb. per indicated horse-power per hour in a compound marine engine constructed with an intermediate superheating vessel, in accordance with his plans; nor are we likely to stop long at this point of comparative perfection, for in the early portion of my address I have endeavored to prove that the theoretical perfection would only be attained if an indicated horse-power was produced with $\frac{1}{5.5}$ lb. of pure carbon, or say ¼ lb. of ordinary steam coal.

Here then we have two distinct margins to work upon, the one up to the limit of say 2 lbs. per horse-power per hour, which has been practically reached in some and may be in all cases, and the other up to the theoretical limit of ¼ lb. per horse-power per hour, which can never be absolutely reached, but which inventive power may and will enable us to approach!

DOMESTIC CONSUMPTION.

The wastefulness of the domestic hearth and kitchen fire is self-evident. Here only the heat radiated from the fire itself is utilized, and the combustion is generally extremely imperfect, because the iron back and excessive supply of cold airs, check combustion before it is half completed. We know that we can heat a room much more economically by means of a German stove; but to this it may be very properly objected that it is cheerless, because we do not see the fire or feel its drying effect on our damp clothing; it does not provide, moreover, in a sufficient degree for ventilation, and makes the room feel stuffy. These are, in my opinion, very po ent objections, and economy would not be worth having if it could only be obtained at the expense of health and comfort. But there is at least one grate that combines an increased amount of comfort with reasonable economy, and which, although accessible to all, is as yet very little used. I refer to Captain Galton's "Ventilating Fireplace," of which you observe a diagram upon the wall. This fireplace does not differ in external appearance from an ordinary grate, except that it has a higher brick back, which is perforated at about mid-height to admit warmed air into the fire to burn a large proportion of the smoke which is usually sent up the chimney unburnt, for no better purpose than to poison the atmosphere we have to breathe.

The chief novelty and merit of Captain Galton's fireplace consists, however, in providing a chamber at the back of the grate, into which air passes directly from without, becomes moderately heated (to 84 deg. Fahr.), and rising in a separate flue, is injected into the room under the ceiling with a force

due to the heated ascending flue. A plenum of pressure is thus established within the room whereby indraughts through doors and windows are avoided, and the air is continually renewed by passing away through the fireplace chimney as usual. Thus the cheerfulness of an open fire, the comfort of a room filled with fresh but moderately warmed air, and great economy of fuel, are happily combined with unquestionable efficiency and simplicity; and yet the grate is little used, although it has been fully described in papers communicated by Captain Galton, and in an elaborate report made by General Morin, le Directeur du Conservatoire des Arts et Metiers of Paris, which has also appeared in the English language.

The slowness with which this unquestionable improvement finds practical application is due, in my opinion, to two circumstances,—the one is, that Captain Galton did not patent his improvement, which makes it nobody's business to force it into use, and the other may be found in the circumstance that houses are, to a great extent, built only to be sold and not to be lived in. A builder thinks it a good speculation to construct a score of houses after a cheap design, in order to sell them, if possible, before completion, and the purchaser immediately puts up the standard bill of "Desirable Residences to Let." You naturally would think that in taking such a house you had only to furnish it to your own mind, and be in the enjoyment of all reasonable creature comfort from the moment you enter the same. This fond hope is destined, however, to cruel disappointment; the first evening you turn on the gas, you find that although the pipes are there, the gas prefers to pass out by the joints into the room instead of by the burners; the water in like manner takes its road through the ceiling, bringing down with it a patch of plaster on to your carpet. But worst of all, the fire-grates (of a size irrespective probably, of the size of the room) absolutely refuse to avail themselves of the chimney flues, preferring to send the volumes of smoke into the room. Plumbers and chimney doctors are now put into requisition, pulling up floors, dirtying carpets, and putting up gaunt-looking chimney-pots; the grates themselves have to be altered again and again, until by slow degrees the house becomes habitable in a degree, although you now only become fully aware of innumerable drawbacks of the arrangements adopted. Nevertheless, the house has been an excellent one to sell, and the builder adopts the same pattern for another block or two in an increasing neighborhood. Why should this builder adopt Captain Galton's fireplace? It will not cost him much, it is true, and it will save the tenant a great deal in his annual coal bill, not to speak of the comfort it would give him and his family; but nobody demands it of him, it would give him some trouble to arrange his details and sub-contracts, which are all settled beforehand, and so he goes on building and selling houses in the usual routine way. Nor will this state of things be altered until the dwellers in houses will take the matter in hand, and absolutely refuse to put up with builders' ways, or, what is still better, get builders who will put up houses in their way. This is done to some extent by building societies, but there is as yet too much of the old leaven left in the trade, and the question itself too little understood.

CONSUMPTION IN SMELTING OPERATIONS.

We now come to the third branch of consumption, the smelting, or metallurgical furnace, which consumes about 40,000,000 of the 120 millions of the fuel produced. Here also is great room for improvement; the actual fuel consumed in heating a ton of iron up to the welding point, or of melting a ton of steel, is more in excess of the theoretical quantity required for these purposes than is the case with regard to the production of steam power and to domestic consumption. Taking the specific heat of iron at .114 and the welding heat at 2,700 deg. F. it would require $2{,}700 \times .144 - 307$ heat units to heat 1 lb. of iron. A pound of pure carbon develops 14,500 heat units, a pound of common coal 12,000, and therefore, one ton of coal should bring 39 tons of iron up to the welding point. In an ordinary re-heating furnace a ton of coal heats only $1\frac{2}{3}$ ton of iron, and therefore produces only $\frac{1}{23}$ part of the maximum theoretical effect. In melting one ton of steel in pots $2\frac{1}{2}$ tons of coke are consumed, and taking the melting point of steel at 3,600 deg. F., the specific heat at .119, it takes $.119 \times 3{,}600 = 428$ heat units to melt a pound of steel, and taking the heat-producing power of common coke also at 12,000 units, one ton of coke ought to be

able to melt 28 tons of steel. The Sheffield pot steel melting furnace therefore only utilizes $\frac{1}{75}$ part of the theoretical heat developed in the combustion. Here, therefore, is a very wide margin for improvement, to which I have specially devoted my attention for many years, and not without the attainment of useful results. I have since the year 1846, or very shortly after the first announcement of the dynamical theory, devoted my attention to a realization of some of the economic results which that theory rendered feasible. I fixed upon the regenerator as the appliance which, without being capable of reproducing heat when once really consumed, is extremely useful for temporarily storing such heat as cannot be immediately utilized, in order to impart it to the fluid or other substance which is employed in continuation of the operation of heating or of generating force.

Without troubling you with an account of the gradual progress of these improvements, I will describe to you shortly the furnace which I now employ for melting steel. This consists of a furnace bed made of very refractory material, such as pure silica sand and silica or Dina's brick, under which four regenerators or chambers filled with checkerwork of brick are arranged in such a manner that a current of combustible gas passes upward through one of these regenerators, while a current of air passes upwards through the adjoining regenerator, in order to meet in combustion at the entrance into the furnace chamber. The products of combustion, instead of passing directly to the chimney as in an ordinary furnace, are directed downwards through the two other regenerators on their way towards the chimney, where they part with their heat to the checkerwork in such manner that the highest degree of heat is imparted to the upper layers, and that the gaseous products reach the chimney comparatively cool (about 300 deg. F.). After going on in this way for half an hour, the currents are reversed by means of suitable reversing valves, and the cold air and combustible gas now enter the furnace chamber, after having taken up heat from the regenerator in the reverse order in which it was deposited, reaching the furnace therefore nearly at the temperature at which the gases of combustion left the same. A great reversion of temperature within the chamber is the result, and the two first-mentioned regenerators are heated to a higher degree than the latter. It is easy to conceive that in that way, heat may be accumulated within the chamber to an apparently unlimited extent, and with a minimum of chimney draught.

Practically the limit is reached at the point where the materials composing the chamber begin to melt. Whereas a theoretical limit also exists in the fact that combustion ceases at a point which has been laid by St. Clair Deville at 5000 deg. Fahr., and which has been called by him the point of dissociation. At this point hydrogen might be mixed with oxygen and yet the two would not combine, showing that combustion really only takes place between the units of temperature of about 500 deg. and 4,500 deg. Fahr.

To return to the regenerative gas-furnace. It is evident that there must be economy where within ordinary limits any degree of heat can be obtained, while the products of combustion pass in the chimney only 300 deg. hot. Practically a ton of steel is melted in this furnace with 12 cwt. of small coal consumed in the gas-producer, which latter may be placed at any reasonable distance from the furnace, and consists of a brick chamber containing several tons of fuel in a state of slow disintegration. In large works, a considerable number of these gas-producers are connected by tubes or flues with a number of furnaces. Collateral advantages in this system of heating, which is now extensively used in this and other countries, are that no smoke is produced, and that the works are not encumbered with solid fuel and ashes.

It is a favorite project of mine, which I have not had an opportunity yet of carrying practically into effect, to place these gas-producers at the bottom of coal pits. A gas shaft would have to be provided to conduct the gas to the surface, the lifting of coal would be saved, and the gas in its ascent would accumulate such an amount of forward pressure that it might be conducted to a distance of several miles to the works or places of consumption. This plan, so far from being dangerous, would insure a perfect ventilation of the mine, and would enable us to utilize those waste deposits of small coal (amounting on the average to 20 per cent.) which are now left unutilized within the mine.

Another plan of the future which has occupied my attention is the supply of towns with heating gas for domestic and manu-

facturing purposes. In the year 1863 a company was formed, with the concurrence of the corporation of Birmingham, to provide such a supply in that town at the rate of 6d. per 1,000 cubic feet; but the Bill necessary for that purpose was thrown out in the Committee of the House of Lords because their Lordships thought that if this was as good a plan as it was represented to be, the existing gas companies would be sure to carry it into effect. I need hardly say that the existing companies have not carried it into effect, having been constituted for another object, and that the realization of the plan itself has been indefinitely postponed.

COAL QUESTION.

Having now passed in review the principal applications of fuel, with a view chiefly to draw the distinction between our actual consumption and the consumption that would result if our most approved practice was made general; and having, moreover, endeavored to prove to you which are the ultimate limits of consumption which are absolutely fixed by theory, but which we shall never be able to realize completely, I will now apply my reasoning to the coal question of the day.

In looking into the "Report of the Select Committee appointed to inquire into the Causes of the present Dearness of Coal," we find that in 1872 no less than 123,000,000 tons of coal were got up from the mines of England and Wales, notwithstanding famine prices and the colliers' strikes. In 1862 the total getting of coal amounted to only 83,500,000, showing a yearly average increase of consumption of 4,000,000 tons. If this progressive increase continues, our consumption will have reached, thirty years hence, the startling figure of 250,000,000 tons per annum, which would probably result in an increase of price very much in excess of limits yet reached. In estimating last year's increase of price, which has every appearance of being permanent, at 8s. per ton all round, and after deducting the 13,000,000 tons which were exported abroad, we find that the British consumer had to pay £44,000,000 more than the market value of former years for his supply of coal—a sufficient sum, one would think, to make him look earnestly into the question of "waste of fuel," which, as I shall presently be able to show, is very great indeed. The Select Committee just quoted sums up its report by the following expression:—"The general conclusion to be drawn from the whole evidence is, that though the production of coal increased in 1872 in a smaller ratio than it had increased in the years immediately preceding, yet, if an adequate supply of labor can be obtained, the increase of production will shortly keep pace with that of the last few years."

This is surely a very insufficient conclusion to be arrived at by a Select Parliamen ary Committee after a long and expensive inquiry, and the worst of it is, that it stands in direct contradiction with the corrected table given in the same report, which shows that the progressive increase of production has been fully maintained during the last two years, having amounted to 5,826,000 for 1871, and 5,717,000 for 1872; whereas the average increase during the last ten years has only been 4,000,000 tons. It is to be hoped that Parliament will not rest satisfied with such a negative result, but will insist to know what can be done to re-establish a proper balance between demand and supply of coal in preventing its conversion into smoke or other equally hurtful or useless forms of energy.

In taking the 105 million tons of coal consumed in this country last year for our basis, I estimate that, if we could make up our minds to consume our coal in a careful and judicious manner, according to our present lights, we should be able to reduce that consumption by 50 million tons. The realization of such an economy would certainly involve very considerable expenditure of capital, and must be a work of time, but what I contend is that our progress in effecting economy ought to be accelerated in order to establish a balance between the present production and the ever-increasing demand for the effects of heat.

In looking through the statistical returns of the progressive increase of population, of steam power employed, and of production of iron and steel, etc., I find that our necessities increase at a rate of not less than 10 per cent. per annum, whereas our coal consumption increases only at the rate of 4 per cent., showing that the balance of 6 per cent. is met by what may be called our "intellectual progress." Now, considering the enormous margin for improvement before us, I contend that we should not rest satisfied with this rate of intellectual progress, which involves an annual deficit of

4,000,000 tons to be met by increased coal consumption, but that we should bring our intellectual progress up to the rate of our industrial progress, by which means we should make the coal production nearly a constant quantity for several generations to come; by which time our successors may be expected to have effected another great step in advance towards the theoretical limit of effect, which, as we have seen, lies so far above any actual result which we have as yet attained to, that an annual consumption of 10 million tons would give more than the equivalent of the heat energy which we actually consume.

SOLAR HEAT.

I have endeavored to show, in the early part of this lecture, that all available energy upon the earth, excepting the tidal wave, is derived from the sun, and that the amount of heat radiated year by year, could be measured by the evaporation of a layer of water 14 ft. thick, spread over the entire surface, which again would be represented by the combustion of a layer of coal, covering our entire globe, 1 ft. in thickness. The amount of heat radiated away from the sun would be represented by the annual combustion of a thickness of coal 17 miles thick, covering its entire surface, and it has been a source of wonderment with natural philosophers how so prodigious an amount of heat could be given off year after year without any appreciable diminution of the sun's heat having become observable.

Recent researches with the spectroscope, chiefly by Norman Lockyer, have thrown much light upon this question. It is now clearly made out that the sun consists near the surface, if not throughout its mass, of gaseous elementary bodies, and in a great measure of hydrogen gas, which cannot combine with the oxygen present, owing to great elevation of temperature (due to the original great compression), which has been estimated at from 20,000 deg. to 22,000 deg. Fahr.

This chemically inert and comparatively dark mass of the sun is surrounded by the photosphere where the gaseous constituents of the sun rush into combustion, owing to reduction of temperature in consequence of their expansion and of radiation of heat into space; this photosphere is surrounded in its turn by the chromosphere, consisting of the products of combustion, which, after being cooled down through further loss of heat by radiation, sink back, owing to their acquired density, towards the centre of the sun, where they become again intensely heated through compression, and are dissociated or split up again into their elements at the expense of internal solar heat. Great convulsions are thus continually produced upon the solar surface, resulting frequently in explosive actions of extraordinary magnitude, when masses of living fire are projected a thousand miles or more upward, giving rise to the phenomena of sun spots and of the corona which is visible during the total eclipses of the sun. The sun may therefore be looked upon in the light of a gigantic gas-furnace, in which the same materials of combustion are used over and over again.

It would be impossible for me at this late hour to enter deeper upon speculations regarding the "regeneration of the sun's heat upon its surface," which question is replete with scientific and also practical interest, because Nature is our safest teacher, and in comprehending the great works of our Creator we shall learn how to utilize to the best advantage those stores of potential energy in the shape of coal which have providentially been placed at our disposal.

ERRONEOUS VIEWS ABOUT STEEL WORKING.

From the "American Manufacturer."

For some two or three weeks past there has been going the rounds of some of the papers an article that had its origin in one of our city papers, and which purports to give the views of a practical man as to certain erroneous opinions entertained by steel workers in regard to overheated steel. The article referred to starts off by saying that "many of the best informed iron and steel manufacturers, instead of understanding the nature of iron and steel, really know but comparatively little about either, having only acquired, as it were, but the alphabet of the business." After this the article proceeds to give the opinion of a "practical man" on one important point in

the working of steel, and in a manner that leaves one to understand that the "practical man" has discovered something not heretofore known about the working of steel.

This "practical man" is said to have an experience of forty years over the forge, and who, according to his own statement, walked in the traditional grooves trod by his predecessors, and without question accepting the common theories of the craft, until accident afforded him an opportunity to examine into some things, which led to a conclusion differing wholly from the commonly received opinions of his fellow-craftsmen. We give the body of the article itself, with our further comments upon it:

"According to our informant, in the language of the shop, when a piece of steel is overheated and flies to pieces under the hammer, it is cast aside as worthless, the opinion obtaining that the life is burned out of it. This jargon of the shop is not unfamiliar to us. We hear it every day among iron workers. Our old steel worker informs us that experience has demonstrated to him the incorrectness of this conclusion, as commonly applied to steel. His statement will be regarded in some quarters as opposed to the recognized principle upon which the steel manufacturer bases his operations. In substance it amounts to this: That the heat ordinarily derived from a forge cannot, as an agency, affect the character of the steel; that steel is not injured by overheating in the forge, and no absolute loss can ensue, save the low percentage lost in scales, as in the working of all hard metals.

"Our old steel worker's mode of reasoning is so simple that we present it as we received it from him. Beginning with the manufacture, he argues (what all will acknowledge) that no forge can produce a heat of half the intensity at which the metal is poured into the flasks. Where steel is subject to intense heat in the forge, the moment the hanger strikes it it parts, not because the principle is in any manner changed, but simply because it possesses less cohesive power. If, instead of throwing the steel, thus easily broken, aside, in the belief that it is ruined, the worker in steel will permit it to lie on his anvil until it falls to a lower temperature, he will find that he can do what he pleases with it; that it has not been in any way injured by the overheating. To prove this, it is only necessary to take up any of the pieces of steel thus cast aside as worthless, reheat them, and place them under the hammer, when it will be found that they can be drawn down in precisely the same manner as before the overheating process. Any workman employed at the numerous forges in this city, in making steel hammers, can satisfy himself upon this point in half an hour's time. Let him take up a fragment of the steel which, when he endeavored to punch the eye of the hammer, flew to pieces, reheat it, and see if he cannot work it as before; if he can do this it follows then that the large percentage of waste growing out of overheating is, in effect, inexcusable where the truth is known."

The argument set forth in the above is, that as cast steel that has been overheated can be still further worked under the hammer, that it has therefore not lost any of its qualities as steel; that because he has found out after "forty years expended over the forge" that a piece of steel that has been overheated, if allowed to lie without hammering or other working until it would cool off to the temperature at which it *should* have been heated, that it has therefore not deteriorated. Our "practical man" seems to suppose that because he can, by a coaxing process, still work steel that has been overheated, that it has therefore no other end to serve beyond, and that the fact of its still retaining its previous qualities is there proven.

The fact still stands, and always will stand, that when steel has been overheated in the forge or in the heating furnace, it has lost very greatly in that which constituted its peculiar qualities; that if it is afterwards applied to any or most of the finer purposes for which steel is used it will be found to fall short of the requirements of the case. The overheating or burning of good cast steel transforms its fine grain to coarse granular particles, coarser in proportion as it has been overheated or burned. This transformation may, to some extent, be arrested by the use of various chemicals, frequently used as a means of economy in preventing so great a loss in the burned steel. But it is nevertheless true that steel is more or less injured by overheating. A piece of steel formed into a tool for turning chilled rolls would be found greatly deficient afterwards, were it overheated in the forge fire, or the same might be said in most cases were it made into taps or dies, for nut and screw

cutting, where it would have to cut hundreds of nuts or screws per day in a machine for that purpose. It is only sophistry, and proven so by much experience, that because steel, in its manufacture, was at a molten heat, that no heat short of that afterwards could alter its nature; while its nature is undoubtedly given to it there, it must not be argued that nothing less than a close approach to that high heat again can alter its nature. In that case it might be said that because a roll was given a *chilled* surface in the casting that it could not be altered in its nature as a *chilled* roll by any subsequent heating, which has been demonstrated as not to be the case. For where chilled cast iron has been heated to a bright red color, while not wholly altered in its nature, it is found to be very much changed. This "practical man" seems to have had his experience in steel working more particularly in the fashioning of hammers, and that because he has discovered that a piece of steel intended to form a hammer, if overheated, can still, if allowed to cool off to a proper working temperature, be punched as readily as if it had been properly heated, endeavors to impress upon the world of steel workers and users, that it is for any and every purpose fully capable of all the requirements of good steel. Men employed at a hundred arts in which carefully worked steel must be used would tell our "practical man" that while the overheating or burning of steel does not ruinously destroy its quality of strength or tenacity of particles forming it, it wholly unfits it for their special purposes, and that its loss is not solely in the "low percentage of scale" formed on it by overheating, but that there is an absolute loss in quality.

The erroneous opinion conveyed in the foregoing article is intended to give information without any use of scientific phraseology, and while we might perhaps more scientifically give the deterioration and consequent change of quality in the material in question, we have thought best to do it simply and divested of all such.

UTILIZING THE HEAT OF LIME-KILNS.*

From the "The English Mechanic and World of Science."

Within a short period almost all the materials used for heating have been doubled in price. This, of course, in a material degree, increases the first cost, and especially when we consider that labor has also become much higher. But the great increase in the first cost is not, after all, such a serious matter as the enormous increase which has taken place in the price of fuel. When a building has been fitted with a good heating apparatus, the expense may reasonably be expected to be done with for years, but this is not the case with fuel, which is a continual and a heavy tax. A great deal has been done in the way of introducing boilers calculated to economize heat and save fuel; but still, as some one has remarked, "no more than a certain amount of heat can be got out of a given quantity of fuel, economize it as you will." Consequently, with the best boiler that can possibly be procured a considerable quantity of fuel must be consumed in comparison with the extent of buildings to be heated. And it is just here that the great value of lime-kiln heating is made apparent. I do not claim for it merely a greater degree of economy than other systems; I claim for it the merit of heating any extent of buildings by hot water entirely free of cost, except the first outlay for materials and construction of the apparatus. The depth of the stoke-hole required is, of course, greater than would be the case for a boiler only, but very little more than is needed for a tubular boiler, from 10 ft. to 12. ft. under the level of the flow pipes will admit of a good-sized apparatus being fixed; 13 ft., with a proper boiler, would be sufficient for an apparatus to heat 3,000 ft. of 4 in. piping. Much less could be made to do, but it would not be so satisfactory. The kiln is built very much in the shape of an egg, with the narrow end downwards, and is lined inside with firebricks or other suitable material; another wall is carried up at the same time and of the same form as the one forming the kiln, but with an intervening space of about 9 in. This space is filled up with sand as the two walls are carried up, the sand being put there for the purpose of

*Read by Mr. Cowan before the Dublin Horticultural Club.

retaining the heat, which it does most effectually. When the kiln has been carried to the proper height, a hot water boiler is placed on the top, and built in just the usual way, but of course there are no fire-bars required, and only one door; this door is the place at which all the fuel and stones are put in, and the burned lime is drawn out at the bottom, a small opening being left there for that purpose, just sufficient to admit of a shovel being introduced. The working of the apparatus is extremely simple, and may be taught to any ordinary garden laborer in a very short time. When the extent of building to be heated is not great, I recommend the use of the ordinary saddle boiler, on account of its cheapness and durability; and the boiler which I have designed especially for the use of this system is simply a saddle boiler with some additions to it, to make it better adapted to this system. In order that the merits of this boiler may be appreciated, it must be understood, that when anthracite coal is used there is almost no smoke and scarcely any soot to collect in the flues, consequently the great object is to confine the heat sufficiently long about the boiler until the greater part of it has been utilized, and it will at once be seen that this boiler is eminently calculated to attain this end; it has, besides, the undeniable advantage of being low, and consequently does not increase the necessity for depth of stoke-hole to a very great degree.

But, it may be asked, why place the boiler on the top of the kiln? why not form the whole, or at least a part of the kiln with the boiler? and thus have the fire right in the centre of it. A very good answer to these questions has been furnished by Mr. Collis of Millmount, Kilkenny.

Mr. Collis says that the kiln which he has worked for four years is 3 ft. 6 in. in diameter, and 12 ft. high. The boiler, a horizontal tubular one, is 4 ft. high, and encircles the kiln near the top, the mouth being left open, and the smoke and smell allowed to make the best of their way out of the place. This kiln and boiler, Mr. Collis tells us, are capable of heating 1,000 ft. of 4-in. pipe sufficiently for ordinary forcing purposes; and, as he wished to heat 2,000 ft., he had to supplement it this spring with an ordinary 3-ft. tubular boiler. Thus, all that Mr. Collis has been able to accomplish with his kiln hitherto is to heat 1,000 ft. of 4-in. piping. I wish particular attention to be paid to this statement, for he tells us that to accomplish this he had to burn 2 tons of culm per week; and more wonderful still, he only burnt 3 tons of stone with his 2 tons of culm. To burn 3 tons of stone in our kilns at Dromore, we require just 14 cwt. of culm, and that amount heats to any required degree, with an ordinary saddle boiler, 1,000 ft. of 4-in. piping; so that Mr. Collis requires just three times the amount of fuel to burn the same quantity of lime, and to accomplish the same amount of heating, which we do, and a boiler probably three times the cost of ours. The one he is building in now cannot have cost much less than £200, and calculating by the same scale which he gives us for the first, must burn about 10 tons of culm per week in order to heat 5,000 ft. of 4-in. pipe. Culm costs him only 8s. 6d. per ton; but how would the case stand if it cost him, as it does us, 25s. per ton? Add to this the smoke and disagreeable smell which must come from an open kiln consuming such an enormous quantity of fuel, and you have a perfect picture of that which has been put forth in one of our leading gardening papers to prove that the system which I am advocating is not new. Mr. Collis says he does not believe that heat can be had free of cost in his locality. Why, if I were in his locality, I should expect to make a handsome profit from the lime besides having the heat free. With regard to the position of the boiler inside or on the top of the kiln, it is well to bear in mind the following fact: When a kiln is formed of firebricks, they get heated to a very high temperature, and very materially assist in the burning of lime; but this is not the case with a hot water boiler—it is kept comparatively cool by the circulating of the water, and thus in place of assisting in the burning of the lime, as the bricks do, it very materially hinders it—so much so that Mr. Collis informs us that it causes the consumption of three times the amount of fuel; and there is another cause for Mr. Collis' want of heating power in proportion to the amount of fuel consumed, namely, that the greater part of his heat passes off by the mouth of the kiln. I think, then, that what I have stated will go far to prove that the top of the kiln is the right place for the boiler, and as my patents secure me equally well in putting it inside the

kiln, you will see that I am only actuated by a desire to show the best means of obtaining the desired end. In order that the kilns may be allowed to continue burning, and the heat at the same time turned off the building which they are heating, I propose to fix the supply-cistern somewhat near the boiler, and to have it somewhat larger than usual; into this cistern I propose to take two pipes in place of one, one from the flow and one from the return pipes, and when the water is shut off all the buildings, it will circulate into the cistern, and the house can thus be kept quite cool, and at the same time abundance of heat kept at hand to turn on at a moment's notice. This is a very simple arrangement, and not at all expensive, and will secure perfect command of the heat at all times. In conclusion, I may state that I expect this system of heating horticultural buildings will bring about a very considerable change in the production of fruit and flowers in this and other countries.

THE METALLURGY OF STEEL.

By THOS. M. DROWN.

From the "American Exchange and Review."

What is steel? This question is now being earnestly asked on all sides. The answers are numerous, but all fail to give universal satisfaction. The difficulty lies in the many-sidedness of the subject. First, there is diversity of chemical composition; second, of physical characters; and third, of mode of manufacture. It may well be considered impossible to give a definition of steel which would include all these various conditions and at the same time be terse and useful. The difficulty is one, too, which has only recently presented itself, owing to the multiplication of new steel processes, so-called, and of new methods of manufacture. When we fairly comprehend the nature and complexity of the subject, it is evident that it is a new name we want, not a new definition. This whole confusion and uncertainty as to what steel really is has arisen since improved processes have enabled us to melt iron *per se*, or with but a very small amount of carbon. This homogeneous product, which is not wrought iron in the ordinary acceptation of that term, soon obtained the name of steel merely from the fact that it was "cast into a malleable ingot." It is this product for which we need a new name. No confusion of ideas exists regarding the nature or properties of blister steel. From its mode of production we know that it is a carburized iron, and that the degree of carburization depends on conditions well understood and under control. When this blister steel is piled into fagots, heated and rolled out, we have shear steel—a better term, for analogy's sake, would be wrought steel; and, when it is melted and cast into ingots, we have cast steel; or, we may simply melt together wrought iron and substances containing carbon in a crucible, and we have a product which no one hesitates to call cast steel. Again, iron produced in the puddling furnace obtains the name wrought iron; and when melted, by whatever means, and cast into ingots, would naturally be called cast iron, were that name not already appropriated. The terms mild and hard, high and low steels, steely iron, etc., have their origin in the attempt to define these products with more precision, but they are not entirely satisfactory. In fact, the whole subject of the metallurgy of steel is in a very crude state. We not only have no nomenclature and no classification, but we know very little of the real nature of steel. In contemplating the immense number of steel processes we are apt to lose sight of the fact that steel, *par excellence*, is a combination of iron and carbon, and that the difference between steel and wrought iron on the one hand, and cast iron on the other, is, in the main, a chemical one. That we cannot draw the lines of demarcation sharply and say here wrought iron ceases and steel begins, and there steel ceases and cast iron begins, is unfortunate; but the essential difference of properties is, on the whole, well marked. There is nothing inherently peculiar or mysterious in steel. The effect of adding carbon to iron is well understood. It renders iron harder and diminishes its malleability, and the degree of its action is proportional to its amount. The transition from soft iron to steel is at the point at which we notice incipient hardening; the transition from steel to cast iron is at the

point where the steel ceases to be malleable. The hardness of steel is due doubtless to the chemical combination of the iron with the carbon, a condition effected, ordinarily, by heating and sudden cooling. Annealing—heating and slow cooling—softens steel by allowing a part of the carbon to separate from its chemical union with the iron. The difference between cast iron and steel, leaving out of consideration extraneous substances, is therefore one of degree only. It matters not how the steel may be produced; if it is malleable and yet contains enough carbon when combined to render it hard, the product is steel.

When we confine ourselves to the study of this typical carbon steel the subject is plain enough; it is only when we bring into the field of study other steels, that the complexity becomes embarrassing. As far as Bessemer and open hearth steels are concerned, there is no reason why we should apply any other rule than that already mentioned, viz., if the product contains enough carbon to harden it, and not enough to destroy its malleability, it is undoubtedly steel. It is difficult to see how the mode of production can in any way affect the question. There are, however, steels, so-called, which owe their properties to other elements, as titanium, tungsten, chromium, and many others. Are we to consider these as distinct species of steel—the tungsten, titanium, etc., replacing carbon—or are they simply carbon steel with modified properties due to the presence of a new element? This question is one which in the present state of our knowledge cannot be answered. Notwithstanding that steels bearing the above names have been for many years prominently brought into notice, and have for a time been regular articles of manufacture, the amount of our knowledge on the subject is lamentably small. The fact probably is, that these substances modify a carbon steel; the existence of a true steel free from carbon has not, as far as we know, been yet produced. There is no field of investigation in iron metallurgy which promises such valuable scientific and practical results as the study of the effects of various elements on the properties of carbon steel. Our knowledge on this point is almost nothing, and the mystery that is thrown around the subject is turned to good account by ignorant men and charlatans. A more subtle investigation, but one equally promising, is the effect of occluded gases—carbonic oxide, carbonic acid, and hydrogen—in steel. The discoveries of Graham and Parry have indicated an entirely new line of research in this direction, one which can scarcely fail to result in valuable practical results. The countenance that is often given by intelligent men to names founded on error or gross ignorance can not be too severely condemned. A notable example of this practice is found in the so-called "silicon" steel. This is a product made from pig iron in a puddling furnace, with the addition of a highly silicious rock containing some iron and alumina. Leaving out of consideration whether the product is steel or not, there certainly is no reason to believe that there is any silicon in it; and the use of the term is therefore to be regretted as leading to misconception, and adding more confusion to an already well-embarrassed subject. We might as well call all crucible steel manganese steel, because oxide of manganese is put into the pot, as to call a substance "silicon" steel because there is plenty of silica in the cinder.

THE GALVANIC BATTERY AS AN ANTI-INCRUSTATOR.

From the "English Mechanic and World of Science."

The high price of coals has rendered boiler-owners more ready to listen to proposed remedies for incrustation than they were, as a rule, when fuel was cheap; and so far the present high price is an evil which has at least one redeeming feature. Steam-users know as well as any one that a boiler thickly coated with scale requires more fuel than it did when new and clean, and they also know that by permitting this scale to accumulate, they are gradually but surely destroying their boilers. So long as fuel is cheap, however, little effort will be made to spare the requisite time for cleaning, and the coals go on and the plates are burned while the scale thickens apace till there is a failure to make the requisite quantity of steam, or something worse. In

what we have to say here, we do not specially address this class of steam-users—a class who will not listen to any improvement in the routine of their daily practice, unless it promises immediate results on the right side of their books, without entailing extra trouble on themselves. To those users of steam who are ever ready to do what they can to test the efficiency of asserted improvements in the working of boilers, we may address a few words on a method of preventing incrustation, which, if all that we have heard be true, is at least worth a trial. We have already referred in a previous article to the advantages said to accrue from the use of tannate of soda, which is alleged to loosen old scale and prevent the formation of new. The application of this salt, like most other proposed remedies, is sometimes attended with inconvenience, and is always liable to abuse or neglect on the part of the attendant. The remedy we have now to mention is that of the galvanic battery, which is asserted to have acted in a remarkably satisfactory manner in America. The use of the "battery" for this purpose has, if we recollect rightly, been patented in this country; but unfortunately for the patentee, we doubt whether he can claim more for his invention than his own special or peculiar mode of applying the current; for the application of the galvanic battery to this purpose is a tolerably old idea now, though, for some reason or other, it has rarely been put in force. It is from America that we hear of the remarkable success that has attended the employment of the electric current, not only for preventing the formation of scale as scale, but also for removing it when formed. One of the railway companies running from Chicago has, it appears, had the "battery" in use on about one hundred locomotives for several years, with results more or less satisfactory —the want of uniformity being, it is asserted, occasioned by the neglect of some of the attendants. A correspondent of one of the American papers says he has seen a locomotive which had been doing duty for five years without any repairs being needed to the boiler, and which, when inspected and thoroughly overhauled, was found perfectly clean inside the shell, with a fire-box in good order, and with only a dozen tubes that required to be replaced. It is alleged that not only does the application of the battery prevent incrustation, and remove it when formed, but it also preserves the characteristic qualities of the metal. Thus we are told that pieces of plate from the fire-boxes of engines carrying the battery retained their soft, tough, and fibrous nature, and were capable of withstanding bending backwards and forwards without breaking; whereas, pieces taken from similar positions in locomotives not furnished with a galvanic battery, could be easily broken with a hammer, like cast iron, the metal being white and crystalline. Whether this result is attributable to the fact that the plates are kept clean, and, consequently, comparatively cool from contact with the water, or to some specific and preservative action of the electric current on the metal itself, is immaterial to the point at issue; for the result is unquestionably due to the battery, directly or indirectly.

This plan of preventing incrustation has been adopted in different parts of America for all descriptions of boiler, and with results more or less satisfactory, according to the attention given to the apparatus. The ordinary Daniell cell is the element which has been principally employed, and, consequently, neglect of the battery has often resulted in disappointment, as regards its effects on the boiler; while the prejudices of many of the attendants have been much against its more general adoption, and we hear of locomotive-drivers breaking the wires of the battery on the approach of a storm, because "they draw the lightning." Compared to any of the really serviceable anti-incrustators in the market, or to any of the time-honored methods of removing scale, attaching a battery and keeping it at work must be at once more economical and less inconvenient, merely involving the usual periodical blowing out. Various methods of connecting the battery to the boiler have been tried, but the principle of all, we believe, is to connect one pole with the water, the other with the outer surface of the shell. It must not, however, be assumed that the passage of the current destroys the scale-producing substances; all that is asserted is that it prevents them adhering to the sides or caking together at the bottom of the boilers. It is obvious, therefore, that the plan depends, in some measure, on the care and attention bestowed on the operation of blowing out. A passage in Mr. Wilson's "Treatise on Steam Boilers," which we reproduced on p. 444, would appear to show that he is inclined to attribute the results, said to be obtained by the battery, to other

and very different means; but, so far as we know, few experiments in this direction have been carried out in this country, and those under the disadvantage of comparative ignorance of the agent employed. But, at any rate, the experiments are worth renewed trial, and especially if it be true that results so satisfactory have been obtained in the United States.

IRON AND STEEL NOTES.

MANUFACTURE OF IRON PLATES.—The rolling of armor-plates has assumed such a remarkable prominence within the last ten or fifteen years, and the nature of the strains to which they are subjected in the actual operations of warfare has been so practically determined, at Shoeburyness and elsewhere, in the ever-continuing struggle between Arms and Armor, that a tough fibrous texture has come to be regarded as the one thing to be attained in the manufacture of plates—*i. e.*, assuming armor-plates to be an indispensable feature of the equipment of a fighting ship, which we greatly doubt—and steel is undoubtedly regarded with considerable distrust as a material for building men-of-war. It seems not a little startling, therefore, to find a proposal in direct contravention of these seemingly well-established principles; and yet such there is, in the patented invention of Mr. Thomas Hampton, steel manufacturer, of Sheffield, who claims as improvements in the manufacture of armor and other plates the employment of the Bessemer process of casting: for he proposes to take hæmatite pig, and other metals suitable to the Bessemer process of steel-making, and to blow them in the converter in the ordinary way, only to thoroughly or partially decarbonize them at will, "or according to circumstances," either before or after the introduction of the spiegeleisen, and then to run the molten metal direct through the ladles into moulds of the size and shape of the required plates. Armor and other plates would thus be neither more nor less than Bessemer pigs of particular form and dimensions—an improvement backwards, on the face of it.

Improvements in rolling-machinery for wire, rods, hoops, and other similar metal sections, constitute the claim of Mr. Isaac Hayward, Warrington, the object being to avoid the defect of crushing instead of closing up the fibre of the metal, which he assumes to cause liability to break up, if the material is not of first-rate quality, from want of a change in the position of the metal section in passing through the rolls. Mr. Hayward's invention provides for such a change in the position of the rod or bar, while being rolled, that it shall pass through every successive pair of rolls at a different angle, whereby the metal would be toughened and not crushed. There are obvious limits within which this may be applicable and advantageous; but when the inventor goes on to claim that the same work will be done with half the power and attendance, we cannot but feel that there are also limits even to blind faith and unquestioning acceptance.

RAILWAY NOTES.

RAILWAYS IN JAPAN.—Of late we have heard a great deal of Japanese progress in many ways, and of their imitation of European institutions generally; but in no respect is this more noticeable than in regard to the recent introduction of the railway system into that country. The construction of railways in Japan is being carried forward with considerable activity, and we may usefully give our readers some information with regard to the subject.

The first railway in Japan was opened last year, and the support which it has received, and the completeness of its management and receipts, cannot fail to give satisfaction to the Japanese Government. This line runs from Yokohama to Shinagawa, and the State opening on the completion of the line to the Yedo terminus took place on the 12th October last. Appropriately to this subject it may be pointed out—although no information is given as to the cost of this line—that railway construction ought to be cheap enough in Japan, as money is easily procurable, material is plentiful and at hand, and labor is cheap. Preliminary outlay, such as Parliamentary expenses, cannot amount to much, while the sums given as compensation must be inconsiderable. So far it is satisfactory to record that the Japanese line above referred to has been worked without accident, which is attributed to the foreign supervision and foreign workmen employed. There is, however, a growing desire on the part of the Japanese to get into their own exclusive management such works as these, but it is stated that the time has by no means arrived when they can dispense with foreign aid.

The total length of the line opened last year is only 18 miles; and amongst those who constitute the *personnel* are one resident engineer, ten engine-drivers, six fitters and smiths, one traffic manager, five travelling inspectors, two medical officers, etc. The wish is expressed in reference to this line that its success, coupled with the enterprise of the Japanese Government in the matter of railway development, will stimulate the sister empire, China, to take steps in a similar direction.

An important new railway, in course of construction in Japan, is that connecting Yedo, Yokohama, Hiogo, and Osaka. This has been projected for some time, but its progress towards completion is very slow. The Yedo and Yokohama section is finished, but, with regard to the other portion, fears are entertained that it will not be completed until next year. The line between Osaka and Kioto has been surveyed, and it is said that a large quantity of material has been prepared, but the order for its construction has not yet been issued. A new railway was also proposed to Tsuruga, but no practical measures have been taken to construct it. This is regretted, as it is mentioned that such a line could scarcely fail to be profitable to the Japanese Government, besides adding very greatly to the commercial facilities of the ports between which the new line would run. Probably, at no distant date, the construction of these railways will be practically carried out.

The first section of the Trunk Railway, intended to connect Yedo and Yokohama with Os-

aka and Hiogo, has been completed, as we before stated, and this first section has been opened with the greatest success. Already it attracts more traffic than it can conveniently carry on a single line of rails. The native public avail themselves of the advantage of the line to the utmost, and thus it appears certain that with these favorable conditions the railway system of Japan, ere long, will take a very material development. The Japanese Government has certainly been enterprising in regard to the matter. Telegraphs have also been largely introduced of late into the country, and nearly all the chief commercial ports have been or are being connected in this way. Altogether, Japanese "progress" is a gratifying sign of the times.—*Iron.*

RAILWAYS IN TURKEY.—From a short official report upon this subject we learn that several parties of Turkish engineers have been recently surveying the province of Aleppo and those adjoining it, with a view to the selection of the best direction for the great line which may at some future time connect India with Europe by railway communication. It has been acknowledged by these engineers that the works would be lighter were the port of Tripoli made the terminus on the Mediterranean, but that the cost of the construction of a harbor there, as also at Suedia, would make Alexandretta more desirable as the port from which the railway should start for the Persian Gulf. The difficulty and expense of bringing either of the two former points into connection with a line from Constantinople through Asia Minor would also have an influence in favor of the selection of Alexandretta. The chief question for settlement, however, seems to be whether it would be more advantageous to take a direct course from the Mediterranean to the Persian Gulf, or to deviate from it in order to pass near the principal towns lying between the two seas. Mr. Haddon, the official engineer, who has given much attention to the subject, expresses the opinion that the direct route would be better than the circuitous one, both for the interests of Turkey and England. So far as Turkey is concerned, it is evident that this railway would be essentially an agricultural line, and should, therefore, not be led out of its ordinary course for the purpose of seeking markets which the existence of cultivation proves to be already accessible to local produce. On the whole it seems probable that the inspection of the engineers above mentioned will result in a recommendation of the more direct line practicable from sea to sea. Appropriately to railways in Turkey, it may also be mentioned that the one rail system, invented by Mr. Haddon, the engineer, under the name of the Pioneer Railway, has fallen through at Aleppo, notwithstanding great prospects of success. The first cost would have been almost less even than that of a carriage road, while the time required for its undertaking would have been months instead of years. It would have doubtless proved most suitable for the Turkish provinces.

THE Northern Pacific Railroad is pushing its way across the Continent with steady progress. Among the latest news from Washington is the fact that the Yellowstone Reservation, through which the road will run for 250 miles, has been purchased from the Indians. This is very important both in its possible effect upon the mining interests of the country as well as for the safety it secures to the railroad. It has long been known that very valuable mining lands lie about the Yellowstone, including mines of cinnabar or mercury ore, which may have as great an effect upon the mercury markets of the world as those in California. If the Washington telegram is true, this promising section will soon be open to settlers. Of the more than 6,000,000 acres contained in the reservation, the railroad would get nearly half. This, as well as the obvious determination of the Government to support, by every means in its power, the company which is building the Northern road, is sufficient to prove the value of the bonds and stock of the concern.

ENGINEERING STRUCTURES.

THE great railroad tunnel in St. Louis is progressing rapidly, and in a very satisfactory manner. The following figures in regard to the work will be of interest The span of the arches of the tunnel, of which there are two, is 14 ft. clear, and the height 17 ft. The arches have a depth of 5 lengths of brick springing from a wall of solid stone, whose foundation is 6 ft. thick; the side walls are 5 ft. thick to the spring line, above which the thickness of the wall is 4 ft.; the centre wall is 3 ft. in thickness. All the brickwork and masonry is set in hydraulic cement. Ten barge loads of Grafton stone are consumed every week and 40,000 brick each day. The various labors connected with the construction of the tunnel give employment to not less than 1,500 men and over 200 teams. To assist Captain Eads in the Engineer Department are the following: One superintending engineer, five assistant engineers, six inspectors of masonry, and one draughtsman, all gentlemen of experience.

SAINT GOTHARD TUNNEL.—The monthly report of the Swiss Federal Council brings the account of the progress of the tunnel down to the end of July.

On the Gœschenen side, and to a distance of 243 metres from the entrance, the granite gneiss had presented few fractures, being a compact mass, but afterwards a bed almost vertical, and 7 metres thick, presented itself, which was of a very different character; the feldspath almost entirely disappeared, was replaced by mica and talc, and finally became schistous, containing chrystals of sulphur pyrites. At the distance of 250 metres from the entrance the rock again assumed its original structure with irregular fissures.

The experiments with the MacKean machines proved that more power was wanted than could be obtained with the provisional air-compressors, so that until more powerful air-engines are provided the six Dubois and François machines have been employed alone, but some modifications have been made in them. The daily work done during the month averaged 1 m. 65 mm.

At the Airolo end of the tunnel the mica schist had assumed a darker color, in consequence of

pretty thick layers of mica and other minerals disseminated throughout the mass, the layers being from 50 to 60 centimetres thick, full of fissures, and traversed by strong veins of quartz. At the distance of 228 metres from the entrance and over a space of 20 metres, the rock became less hard and more friable, and presented again many argillaceous strata; it then reassumed its former hardness, veins of quartz reappeared, but the strata was very irregular, and the rock full of fissures. In consequence of the composition of the rock indicated, the water poured through in a continual rain from the roof of the tunnel over a distance of 30 metres. Four Dubois and François machines were worked as before at this end, and the daily work averaged 1 m. 53 mm.

At the end of the month the drift way had been advanced 125 m. 8 mm., and the tunnel was completed over a distance of 453 metres. The maximum number of workmen employed during the work was 1,150.—*Iron.*

THE ST. GOTHARD RAILWAY.—The works of the St. Gothard tunnel are progressing most favorably, and on the 25th of last month 5.90 of heading was driven at the Airolo, and on the following day the amount of progress made was six metres. The contractor, M. Favre, to encourage the workmen, has wisely offered a premium to the miners should the length driven exceed that established by him as a proper day's work. The great difficulties that were met with at first, from the quantity of water which hindered the progress of the work of tunnelling at this end, have in a great measure been overcome; and as the length of heading increases, there is every reason to anticipate that very little water will be met with.

The tunnelling machines used at this side are those known as the system Dubois and François, and are similar to those adopted by the "Société de Charbon de Marihaye," and by the "Companie pour l extraction de l'huile minerale à Anzin." The total length of these machines is 2.20; their width, 0 23; and height, 0.32 The diameter of the cylinder is 0.07, and weight 220 kilogrammes. Six of these "perforators" are mounted on a carriage, similar to those used at the Mount Cenis tunnel, running on rails, which are laid down as the work proceeds, and worked backwards and forwards as required by the little locomotive "Tessin."

With the Dubois and François boring machine a hole from 15 to 20 cent. in depth per minute can be drilled in schist, and in calcareous rock the rate of progress is estimated to be twenty times greater than by hand.

At the entrance to the tunnel the valley has assumed a most animated appearance, and the little mountain village of Airolo has now the aspect of a manufacturing town; upwards of a hundred houses have been built for the accommodation of the workpeople, who are, for the greater part, Piedmontese. Five large buildings have been established near the works, one of which is used for workshops, another for the engineering staff, a third for the steam-engines which are used at present for driving the tunnelling machinery. In the largest building will be placed the great compressors, which will be used later on for compressing the air for the boring machines; and a canal is now being made from the Ticino, at a great height above this building, which will furnish the motive power for driving the compressors. The construction of this canal, which is being cut in the solid rock, is progressing rapidly.

The works of the railway, from Bellinzona to Biasco and from Biasco to Faido, are commenced in several points. At Lugano the works are already commenced near the road to which it runs parallel, as also a tunnel near the Mont St. Salvatore.

The ruins of the Castle of Underwalden, at Bellinzona, have been purchased by a company, who intend building a large hotel from which a magnificent view of the valley of the Ticino, as far as the Lago Maggiore, is obtained.

During the month of July the following progress was made at the tunnel:—

At the north end, at Goeschenen, the length of heading driven during the month was 51 metres, making a total of 259 metres driven up to the 31st July. The length of tunnel completely excavated was increased from 15 metres to 203 metres at that end At the south end, at Airolo, 47 metres of heading were driven, making a length of 266 driven up to the end of July. The length of tunnel completely opened out was increased from 214 metres to 53 metres. The total length of heading driven up to the above date was 525 metres, and the length of tunnel completely excavated. 453 metres. The average number of workmen employed during the month of July was 945, and the greatest number employed in one day at these works was 1,159.

ORDNANCE AND NAVAL.

THE NEEDLE GUN.—The most remarkable object amongst the weapons exhibited at Vienna by Dreyse, of Sömmerda, says the "Oesterr-ungar Wehrzietung," is an infantry rifle for metal cartridges of an entirely new pattern and peculiar construction, which, on account of its many excellencies, seems destined to occupy a foremost place amongst known fire-arms. The lock of the gun is an improved needle-lock arranged for self-cocking, and combines the simplicity and solidity of the needle system with quick and convenient loading, with rapidity of firing equal to the best rifles. The lock consists of six parts, and the loading requires only three movements: the opening of the chamber, by which operation the lock is cocked at the same time; throwing in one of the cartridges into its bed, it not being necessary to put it in exactly: and closing of the chamber. The gun is now ready for firing. The empty cartridge is ejected at the next opening by means of an extractor fixed at the movable round of the chamber. The maximum number of shots per minute is twenty-four. The gun is constructed for ignition by pin or needle, as an exhibited chamber-round with screwed-in needle shows; the latter has only to be substituted for the chamber-round with pin when a change is desired. Both kinds of metal cartridges, for pin and needle ignition, are shown just below the rifle. The advantages of this weapon in the field are essentially the same as those which three campaigns have shown the needle-gun to possess, viz. simplicity, solidity, and

durability. It is very well known that the needle-gun has not undergone any repairs worth mentioning during its long period of almost constant use. Even after campaigns the repairs have been confined to such as naturally arise through eventualities of war: thorough repairs, caused by general wear and tear, have not in a single instance been found necessary. The needle-gun has consequently proved, besides its original low cost, the cheapest of all breech-loaders, and the new rifle is said to possess these advantages in a still greater degree. All its parts are so simple and solid that repairs must be but trifling. The imperfections at present attaching to the needle-gun, such as inferior range, defective trajectory, comparative slowness of firing, have been removed in the present rifle by the application of the smaller calibre (11 millim.) of the metal cartridge with heavy charge of powder and the above-mentioned change in the construction of the lock. One great advantage of this construction is that the lock may be taken to pieces and put together again without the use of any implement; injured parts can be consequently replaced even in the field, and other irregularities of movement as speedily rectified. The great simplicity and solidity of the separate parts gives great durability. The lock, like that of the needle-gun, is so constructed as not to be injured by the intrusion of dust or wet. The lock is secured in the same way as that of the needle-gun, the spiral spring propelling the igniting pin being left loose. By this means accidents from sudden explosions are entirely prevented; an advantage which cannot be too highly valued compared with other guns, where the action of the spring is only stopped, the spring itself remaining firm. As regards the manufacture, all other parts of the weapon can be easily made by machinery and without complicated plant, which consequently reduces the cost price considerably. If we consider all these combined advantages, it seems undoubted that this gun ranks foremost among the best existing small arms. It is reported that the new infantry rifle adopted by the Prussian Government is very much like the one we have described, but it differs from it by greater complication of the lock, which it is more difficult for the soldier to understand; and also that it can only be taken to pieces by means of tools. For these reasons engineers who have seen it predict its shorter durability.

A Vessel 109 Years Old.—The Philadelphia evening "Telegraph" of Sept. 9th, says: The bark, True Love, Captain Thomas Wetherill, has just arrived from Greenland with a cargo of kryolite, that will be landed at Greenwich Point to-day or to-morrow. This vessel was built in the year 1764, and is consequently one hundred and nine years old. The sides batter inwards to the top of the gunwale, and this makes the vessel much broader at the waterline than on deck. In nautical language the sides are known as "tumbling home," because they fall in above the bends.

This bark was built at Philadelphia, but it cannot be ascertained with any degree of certainty at what particular point. The Custom House register does not contain the record, because the vessel was built twelve years before the beginning of the American Revolution. It is most likely that she was built in Kensington, as it appears from history that the first shipyards on the Delaware were established in that locality, not far from the Penn treaty ground. The bark was built for parties residing in Hull, England, and still hails from that place, and for forty-seven years was engaged in the whaling business in the Northern seas, and appeared to be at home among the icebergs of the Arctic region. It is understood that the vessel has never required any considerable repairs. The original timbers appear to be as sound as the day they were erected on the stocks in old Kensington. The bark registers 296 tons, but will carry much more.

The "Militair Worhenblatt" presents some interesting statistics of the consumption of powder by German artillery during the late war. According to these figures the Prussian artillery, including the Baden and Hesse regiments, comprised 79 light, 38 heavy, and 38 horse batteries, besides 19 light and 10 heavy reserve batteries, which were only formed after the war was declared—together, 224 field batteries, of 6 guns each, or 1,344 guns. The field guns are of two calibres, the light and heavy, with a bore of 8 centimetres, the heavy of 9 centimetres. They fired during the whole campaign 267,975 rounds in all, which is far less than is generally believed: the light batteries 112,770, the heavy 107,126, and the horse batteries 48,079 rounds, or each gun fired, on an average, 199 rounds, of which number each light gun fired 191, each heavy, 203, and each horse, 210 on an average. As the batteries carry in the ammunition carriage of each 8-centimetre gun 157, and of each 9-centrimetre gun 133 rounds, they consequently fired, the light guns, 123 per cent.; the heavy, 153; and the horse, 134 per cent. —that is, they had to replenish 23, 53, and 34 per cent. respectively from the ammunition columns, which followed in the wake of the advancing armies. The Bavarian artillery consisted of 12 light, 22 heavy, and two 12-pounder batteries, or 216 guns, which spent 56,211 rounds, or as much as 260 rounds per gun, while the Saxons had 48 8-centimetre guns, and 48 9-centimetre guns, and fired 8,007 and 7,514 rounds respectively, or 167 and 157 per each light or heavy gun, or 162 rounds on average. The figures of Wurtemberg are not yet published, but may be estimated at three-fourths of those shown by Saxony. Thus the total of ammunition spent would be for the whole German field artillery about 3 0,000 rounds, and if, allowing one-half to light, and half to heavy guns, and the weight of light shells to be 9 lbs., that of heavy shells, 1 .3 lbs., English, the weight of all ammunition fired is equal to 1,933 tons, or, out of the number of 1,728 guns, each gun has, on an average, spent 1,119 tons of iron shells.—*Iron Age.*

Steel and Bronze Guns.—General Morin presented to the Academy of Sciences the other day the "Revue d'Artillerie," containing an account of comparative experiments with bronze and steel guns, which deserves attention. Before the late war broke out, experiments were made with three bronze guns of calibre No. 4, so called, but which fired shells weighing 4.50 to 4.90 kilogrammes with leaden jacket. These guns were the invention of Colonel Ortz: they were breech-loaders, and were found to carry 6,000 metres.

Comparing these results with others obtained with steel guns, it has been found that the latter exhibit a superiority of about 60 metres. It is established, moreover says Captain Guespereau, member of the commission for gun experiments at Calais, that steel presents more accuracy than bronze. These two cases of superiority on the side of steel guns may be to a great extent attributed to the fact of the co-efficient of elasticity being much higher in steel than in bronze; steel guns dilate more than those made of bronze, while they are far less affected in form by firing, and consequently cause much less sensible deviations on the part of the projectiles. The hardness of steel, its great resistance to rupture, the ductility of that which is called soft steel, make up a collection of qualities which alone can meet the new conditions imposed on artillery. The same series of experiments proved the superiority of the new gunpowder prepared at Bouchet, on the plan of Captain Castan, on the score of ballistic power, and superior velocity at 500 metres, as well as with respect to the progressive production of gases, and the diminution of their maximum tension.

BROADWELL'S breech-loading ordnance is illustrated in its application by two guns, a 9-pounder field piece and a 2½ in. Cal. mountain gun. It is stated that this system has been adopted by Russia, Prussia, Austria, Italy, France, Switzerland, Turkey, and other countries, and has been applied by Mr. Krupp to guns of all calibres fabricated by him. It was adopted by the Imperial Russian Government in 1865, and has since been applied to all their artillery from 12-in. calibre to the mountain gun, and is still adhered to. The system has for many years been in use by the Prussian Government, by whom it is now being applied to guns of all calibres.

BOOK NOTICES.

POCKET-BOOK OF THE PRACTICAL RULES FOR THE PROPORTIONS OF MODERN ENGINES AND BOILERS FOR LAND AND MARINE PURPOSES. By N. P. BURGH, Engineer. Fourth Edition. 1873. For sale by D. Van Nostrand. $1.75.

The honor of having arrived at a fourth edition is a sufficient testimony to the "Practical Rules" of this neatly got-up Pocket-book. In it the accepted proportions of the most effective engines and boilers are minutely given with all their necessary adjuncts; added to which there is an Appendix of information relating to engines and boilers, such as the "bursting and safe-working pressure of boilers," "strength of boilers," "strains of engines,' "friction of engines," etc., which should be in the hands and heads of all engineers. So far we can speak in commendation, but we cannot close without a reference to the jargon, miscalled English, in which the work is written. The Preface states that "the introduction of this work is for the purpose of rendering in detail complete the practical proportions of modern engines and boilers, so as to enable the student to readily understand the higher branches of the profession, also to assist the memory of the conversant." To prove to the reader that the Preface, as sometimes happens, is not by another hand, we quote from p. 76 on "oscillating engines," which are thus described:—"The use of these engines for marine purposes has been proved to be applicable for the paddle-wheel, but the excessive friction (caused by the vibration of the cylinder) on the piston-rod, also that of the trunnions, render it necessary that the piston-rod and crank-shaft have larger proportions than for engines adapted for the screw." Nor is this want of plain idiomatic English the only fault of its style, as in many cases the language even leads to obscurity. Every "engineer" is not expected to write like Addison, but at least we expect that a book for students should have its language made grammatical and idiomatic before it is used, a task which might be performed by deputy, if it were considered beneath the consideration of an "engineer," which we do not believe it to be, even on the ground of clearness of definition.—*Ed.*

ELEMENTS OF MINERALOGY, containing a general Introduction to the Science, with descriptions of the Species. By JAMES NICOL, F. R. S. E., F. G. S., Professor of Natural History in the University of Aberdeen. Second edition. Edinburgh: Adam and Charles Black. For sale by D. Van Nostrand. $3.75.

Amongst the natural sciences, the study of which is now acknowledged to be essential in the thorough education of practical men, mineralogy occupies a prominent place, and there are perhaps few works calculated so readily to convey to the student the necessary information upon the subject as Prof. Nicol's manual, a new edition of which has just been issued, for it combines conciseness with completeness to the utmost possible extent. The volume is precisely that which the student requires, since it supplies every detail with such minuteness that he may readily refresh his memory with regard to any fact which his instructor may have mentioned in the course of his lectures. One most important object of a treatise on Mineralogy, as Prof. Nicol remarks, is to give such descriptions of minerals, their essential properties and distinctive characters, as will enable the student to distinguish the various species, and to recognize them when he meets with them in nature; and to accomplish this he must first become acquainted with the terminology, or nomenclature, of the science; yet by far too frequently the whole of the information upon this portion of the subject is given incidentally. In Prof. Nicol's treatise, on the contrary, the chapter on the form of minerals is particularly full and explicit.

The chapter on the physical properties of minerals is no less complete, the utmost care being taken to afford all necessary information concerning cleavage and fracture, hardness and tenacity, specific gravity, lustre and color, and phosphorescence, electricity, and magnetism, in a style which the student will comprehend with the greatest facility. In the chapter on the Chemical Properties of Minerals, Professor Nicol retains the Berzelian formulæ, which he considers are from their short condensed form more readily caught by the eye, and more easily remembered, than any that have been substituted for them. He has, however, in his tables given both the old and the new formulæ, though he has not gone very far to show the relative advantages, or the reasons urged for

adopting each; but this is probably immaterial, as opinions are widely different as to the system of formulæ which it is most desirable to adopt, and until there is more unanimity the Berzelian is at least as good as any other, whilst to explain the theories upon which the several systems are based would require a volume. The last chapter of the first part treats of the classification of minerals, and, with those which precede it, gives every necessary facility for the profitable study of the second part of the volume, in which the descriptions of the mineral species are given.

The volume is altogether as complete and explanatory as could be desired, and for the student who has the advantage of a teacher of only ordinary intelligence there is probably no elementary manual which could be turned to, which would afford him greater assistance in refreshing his memory of the facts he had been taught, or in filling up the more minute details connected with the subject. The book is in every respect worthy of the highest commendation.

ELEMENTS OF PHYSICAL MANIPULATION. By EDWARD C. PICKERING, Professor of Physics in Massachusetts Institute of Technology. New York: Hurd & Houghton. For sale by Van Nostrand. $3.

This work affords new suggestions to instructors in physical science. It aims to guide the student in general physics in a laboratory course parallel with that of practical chemical analysis.

Physical laboratories or workshops have been projected for several of our leading scientific schools, in which the lead of the Institute of Technology has been followed.

In so new a field of instruction a competent text-book is a prominent necessity. The work of Prof. Pickering seems all that could be desired at present. The most explicit directions are given respecting the method of conducting experiments whether for exhibition or investigation in all departments of so called general physics.

TRAITÉ COMPLET DES CHEMINS DE FER ECONOMIQUES. Par C A. OPPERMANN. Paris: Dunod. For sale by Van Nostrand. $14.

Judging from the dimensions of this work there is good reason to believe it "complet." There are six hundred quarto pages of descriptive text, and about one hundred pages of engraved diagrams.

The topics to which most space is devoted are: Road-bed and Superstructure—Rolling Stock—Retaining Walls—Bridges and Viaducts—Tunnels—Depots and Way Stations Working the Road—Systematic working of the trains, and methods of transportation of different kinds of freight. —Special legislation for Railways—Execution of Contracts. —Acquisition of Lands.

An appendix devotes considerable space to Tramways of Paris and London.

WHAT A HOUSE SHOULD BE *versus* DEATH IN THE HOUSE. By WILLIAM BARDWELL. London: Dean & Son. For sale by Van Nostrand. $1.75.

Mr. Bardwell's new book. entitled "What a House should be *versus* Death in the House," is a well-timed admonition, and, addressed mainly as it is to the public itself, and that in strong, terse, forcible terms, we trust it will produce an effect which may not prove as transient and illusory as most of those heretofore have done.

The treatment of the work is terse and pithy, as it should be, and the arrangement of the chapters under the heads of "The Bane" and "The Antidote," effective. The latter is subdivided into matters relating to water, earth, fire, and air, and contains many valuable hints connected with each branch. At the end of the book are a series of sanitary receipts. In a view forming the frontispiece, as well as in a plan in the body of the work, the author's notion as to what a house should be in the shape of a detached villa has been worked out in a design by Mr. Seddon. This seems to comprise a glass roof for a conservatory at the top, and the closet is separated from the house by a smaller conservatory below. The book, though slight in execution, is a well-timed and useful contribution on a subject of great practical importance to the public.

CARBONIZATION DES BOIS EN VASES CLOS ET UTILIZATION DES PRODUITS DÉRIVÉS. Par CAMILLE VINCENT. Paris: Gauthier-Villars. For sale by Van Nostrand. $2.

After describing the method of distilling wood, the author of this work proceeds to discuss the chemical processes necessary to secure the various products.

The book is well printed and finely illustrated, but is quite technical in describing chemical processes.

CARBONIZATION DU BOIS ET EMPLOI DU COMBUSTIBLE DANS LA METALLURGIE DU FER. Par A. GILLOT. Paris: Lacroix. For sale by Van Nostrand. $5.60.

This work is in two distinct parts, each quite complete as a treatise. The first deals with carbonization only, and describes the French methods, which are known to be very complete. The second part relates to the employment of the products in the iron and steel processes, and there is much elaborate ciphering to prove the plan a profitable one in France.

TRAVAUX PUBLIES DES ETATS UNIS D'AMERIQUE EN 1871. Rapport des Mission. Par M. MALEZIEUX, Ingenieur en Chef. Paris: Dunod. For sale by Van Nostrand. $28.

This magnificent report deserves that enlargement of its circle of readers which a translation into English can alone insure. The detailed descriptions of the great engineering works now in progress in this country, are so admirably rendered in every way, that a wide circulation of the report seems eminently desirable. The kindly appreciative spirit in which the talented author writes of our recent exploits in engineering, may be inferred from the closing paragraph.

"Without losing sight of what is purely utilitarian, the Americans have given to their works astonishing dimensions. Champollion said of the monuments of Egypt that they seemed to have been built by giants, and for giants. But a feeling of oppression overcomes us when we think of the muscular force which armies of slaves have *there* expended.

"But the Americans seem in the architecture of

their public works to have abandoned the time-honored unit of measure, and to have established a larger one in its place. But to their eternal honor in relieving man from his ancient role of beast of burden, they have transformed into palpable reality the sovereignty of mind over matter."

The report including the plates fills two large quarto volumes.

TREATISE ON THE APPLICATION OF ZORE'S TRUNCATED IRON TO FLOORS, ROOFS AND BRIDGES. By P. SCHWAEBLE. Edinburgh: Thomas Scott. For sale by Van Nostrand. $1.

This form of section for iron beams originated, we believe, in France, but it finds many advocates in other countries. It is a substitute for the H or T sections, in such common use at present. The "Zore" cross section is a V section, with heavy flanges turned outward at the end of each branch, and the vertex exchanged for a flat area parallel to the flanges. The thickness of the top plate and flanges is somewhat greater than that of the sides or branches.

The pamphlet discusses the merits of this peculiar form, giving formulas and tabulated results of calculations from them for all required dimensions of the beams.

THE WATER WORKS OF BROOKLYN. For sale by Van Nostrand. 25c.

This brief description of an extensive work is designed to answer the popular inquiries regarding the character and extent of the Brooklyn water supply.

The history of the project is shortly sketched, and a brief description of the natural and artificial reservoirs. The pamphlet, which is exceedingly minute, contains matter of local interest chiefly, and given in a semi-scientific manner, the better to suit a wide circle of inquirers.

MISCELLANEOUS.

ASPHALT PAPER.—Asphalt paper is likely to become of great use in many ways. In thin sheets it is useful for wrapping silks or other fabrics that need protection from moisture, for lining cases, or packing boxes for pianos, etc., or rolled up into pipes for conveying water. Asphalt tubes are only one-fifth the weight of iron, will not rust, and are quite tough and strong. The tubes are simply sheets of paper, of a peculiar quality, dipped in melted asphalt, and then rolled upon a cylinder. A machine for preparing the asphalt wrapping paper consists of a hollow cylinder, heated by steam, and a wedge-shaped box, containing the hot asphalt. The box has a narrow slit, the width of the paper, and as the paper passes, a thin layer of asphalt is distributed on the paper just before it passes the cylinder.

ANCIENT TIMBER.—Probably the oldest timber in the world, which has been subjected to the use of man, is that which is found in the ancient temples of Egypt. It is found in connection with stone work, which is known to be at least 4,000 years old. This wood, and the only wood used in the construction of the temple, is in the form of ties, holding the end of one stone to another in its upper surface. When two blocks were laid in place, then it appears that an excavation about an inch deep was made in each block, into which an hour-glass shaped tie was driven. It is therefore very difficult to force any stone from its position. The ties appear to have been the tamarisk, or shittim wood, of which the ark was constructed, a sacred tree in ancient Egypt, and now very rarely found in the valley of the Nile. These dovetailed ties are just as sound now as on the day of their insertion. Although fuel is extremely scarce in that country, these bits of wood are not large enough to make it an object with Arabs to heave off layer after layer of heavy stone for so small a prize. Had they been of bronze, half the old temples would have been destroyed ages ago, so precious would they have been for various purposes.

THE Lackawanna Iron and Coal Company, Scranton, Pa., have erected a new cupola furnace which is 67 ft. high, and at the boshes 23 ft. diameter. The capacity of the furnace will exceed 300 tons per week, and its cost will reach $200,000. Being a large furnace, it is of course heralded as the largest in the world, but this is not true. The highest furnace is 102 ft. high, and the widest has boshes of 30 or 33 ft. diameter.—*Engineering and Mining Journal.*

UNIFORM time for the railways of the country promises to be secured by regulating the clocks in the depots of the leading lines in the principal cities by the clock in the Western Union office, at New York, as that is regulated from Washington. These clocks will have two sets of hands, operated by the same movement, and indicating at once the standard and the local time. One in the telegraph office at Port Hastings, Cape Breton, shows the difference of 50 min. 10 sec. and 14-60 of a second between Port Hastings and New York. A clock to be placed at the terminus of the French cable in Duxbury, Mass., will show the time of Washington and Greenwich together. The Washington time will be furnished from the telegraph office in New York, while the Greenwich will be transmitted by cable. It is not yet decided whether Washington or New York will be made the basis. New York time was in vogue on most of the Eastern Railways and as far west as Buffalo, but there is no rule in the matter. The proposed system will change all that, and mistakes arising from the want of a regulated time will no longer occur.

THE PROJECTED CANAL THROUGH THE ISTHMUS OF CORINTH.—According to the "Levant Herald" it appears that the concession for the canal through the Isthmus of Corinth has been granted by the Greek Government to a Greek banker of London. This concession includes a grant of 30 millions of square yards of land for building purposes, docks, etc., the mines and forests in the neighborhood of the canal, the mineral springs of Zutraki, railroads and tramways, the Lake of Stymphalia for irrigation, the monopoly of the navigation, and numerous other privileges. This undertaking is said to be looked upon favorably in the Levant.